CLIMATE-SMART Agriculture 2015

Global Science Conference

March 16-18, 2015
Le Corum, Montpellier France

Parallel Session L2

Climate-smart Strategies

Tuesday, 17 March 2015

14:00–18:00

Content

ORAL PRESENTATIONS

PARALLEL SESSION L2.1 DEVELOPING AND EVALUATING CLIMATE-SMART PRACTICES

KEYNOTE PRESENTATIONS

14:00 Developing and evaluating climate-smart practices and services

Campbell Bruce M.[1], Corner-Dolloff C.[2], Girvetz E.H.[3], Rosenstock T.[4]

[1]*CIAT, c/o University of Copenhagen, Copenhagen, Denmark*

[2]*CIAT, Cali, Colombia*

[3]*CIAT, Nairobi, Kenya*

[4]*ICRAF, Nairobi, Kenya*

14:30 Evaluating agricultural mitigation and scaling up climate-smart practices using the FAO EX-Ante Carbon balance Tool

Bernoux Martial[1], Bockel Louis[2], Grewer Uwe[2], François Jean-Luc[3], Rossin Nicolas[4], Braimoh Ademola[5]

[1]*IRD, UMR Eco&Sols, 34060 Montpellier, France*

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[4]*AFD, CLI, Paris, France*

[5]*World Bank, Washington DC, USA*

CONTRIBUTED ORAL PRESENTATIONS

16:30 Rain water-based integrated agricultural system: a model for ensuring food security and adaptation in coastal Bangladesh

Talukder Byomkesh[1], Blay-Palmer Alison[1], van Loon Gary[2]

[1]*Department of Geography and Environmental Studies, Wilfrid Laurier University, Waterloo, Canada*

[2]*School of Environmental Studies, Queen's University, Kingston, Canada*

16:45 Additive impacts of climate-smart agriculture practices in mixed crop-livestock systems in Burkina Faso

Rigolot Cyrille[1,2], De Voil P.[3], Douxchamps Sabine[4], Prestwidge Di[1], Van Wijk Mark[5], Thornton Phillip[6], Henderson B.[1], Medina Hidalgo D.[1], Rodriguez Daniel[3], Herrero Mario[1]

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[3]*University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Toowoomba, Australia*

[4]*International Livestock Research Institute (ILRI), Ouagadougou, Burkina Faso*

[5]*International Livestock Research Institute (ILRI), PO Box 30709-00100, Nairobi, Kenya*

[6]*CGIAR Research Programme on Climate Change, Agriculture and Food Security, (CCAFS), PO Box 30709-00100, Nairobi, Kenya*

17:00 Developing indicators for Climate-Smart Agriculture (CSA)

Rawlins Maurice Andres, Heumesser Christine, Emenanjo Ijeoma, Zhao Yuxuan, Braimoh Ademola
The World Bank Group, 1818 H St. NW, Washington DC, USA

17:15 Towards metrics to track and assess climate smart agriculture

Verhagen Jan, Huib Hengsdijk, Sjaak Conijn, Annemarie Groot, Nico Polman, Theun Vellinga, Eddy Moors
Wageningen UR, droevendaalsesteeg 4, 6708 pb, Wageningen, the Netherlands

PARALLEL SESSION L2.2 FACING CLIMATIC VARIABILITY AND EXTREMES

KEYNOTE PRESENTATIONS

14:00 Facing climatic variability and extremes

Zougmoré Robert[1], Rao K.P.C.[2], Diedhiou Arona[3]
[1]*ICRISAT-Mali, BP 320 Bamako Mali*
[2]*ICRISAT Ethiopia, PO Box 5689, Addis Ababa, Ethiopia*
[3]*Université de Grenoble, BP 53, 38041, Grenoble Cedex 9, France*

14:30 Rainfall modifications in the context of climate change: the puzzle of the tropical regions

Lebel Thierry, Vischel Théo
LTHE, IRD & Université de Grenoble, BP 53, 38041, Grenoble Cedex 9, France

CONTRIBUTED ORAL PRESENTATIONS

16:30 The potential for underutilised crops to improve food security in the face of climate change

Massawe Festo[1], Mayes Sean[1,2], Cheng A.[1], Chai, H.H.[1], Cleasby P.[1], Symonds R.[1]; Ho W.K.[2], Siise Aliyu[1], Wong Q.[1], Kendabie P.[3], Yanusa Y.[4], Azman R.[2], Azam-Ali Sayed N.[2]
[1]*University of Nottingham Malaysia Campus, Malaysia*
[2]*Crops for the Future, Malaysia*
[3]*University of Nottingham, United Kingdom*
[4]*Bayero University Kano, Nigeria*

16:45 Changes in climate variability and potential for impacts of droughts on agricultural markets

Leclère David, Havlík Petr
International Institute for Applied System Analysis (IIASA), Ecosystem Services Management program (ESM), Laxenburg, Austria

17:00 How precisely do maize crop models simulate the impact of climate change variables on yields and water use?

Durand Jean-Louis[1], Bassu Simona[2], Brisson Nadine[2], Boote Kenneth[3], Lizaso Jon[4], Jones James W.[5], Rosenzweig Cynthia[6], Ruane Alex C.[6], Adam Myriam[7], Baron Christian[8], Basso Bruno[9,10], Biernath Christian[11], Boogaard Hendrik[12], Conijn Sjaak[13], Corbeels Marc[14], Deryng Delphine[15], de Sanctis Giacomo[16], Gayler Sebastian[17], Grassini Patricio[18], Hatfield Jerry[19], Hoek Steven[12], Izaurralde Cesar[20], Jongschaap Raymond R .[13], Kemanian Armen R.[21], Kersebaum K. Christian[22], Kim Soo-Hyung[23], Kumar Naresh S.[24], Makowski David[2], Müller Christoph[25], Nendel Claas[22], Priesack Eckart[11], Pravia Maria Virginia[21], Sau Federico[4], Shcherbak Iurii[9,10], Tao Fulu[26], Teixeira Edmar[27], Timlin Dennis[28], Waha Katharina[24]
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[27]Sustainable Production, The New Zealand Institut for Plant & Food Research Limited, Lincoln, Canterbury, New Zealand
[28]Crop Systems and Global Change Laboratory, USDA/ARS, 10300 Baltimore avenue, BLDG 001 BARC-WEST, Beltsville, 20705-2350 MD, USA

17:15 Modeling livestock production under climate constraint in the African drylands to identify interventions for adaptation

Mottet Anne[1], Conchedda Giulia[1], de Haan Cees[2], Msangi S.[3], Ham Frédéric[4], Lesnoff Matthieu[5], Fillol, Erwann[4], Ickovicz Alexandre[6], Cervigni Raffaello[2], Gerber Pierre[1]
[1]FAO, 1Viale delle Terme di Caracalla 00153 Rome, Italy
[2]World Bank, 1818 H St NW, Washington, DC 20433, USA

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[4]*ACF West Africa Regional Office, Yoff Toundoup, RYA lot No. 11, Dakar, Senegal*
[5]*CIRAD, Campus de Baillarguet, TA C-112 / A, 34398 Montpellier Cedex 5, France*
[6]*CIRAD, Campus Montpellier SupAgro-INRA, 2, place P. Viala, 34060 Montpellier cedex 1, France*

PARALLEL SESSION L2.3 COMBINING MITIGATION, ADAPTATION AND SUSTAINABLE INTENSIFICATION

KEYNOTE PRESENTATIONS

14:00 Ex-ante evaluation of Climate-Smart Agriculture options

Cassman Kenneth[1], van Ittersum M. K.[2], Hochman Z.[3], McIntosh P.[3], Grassini P.[1], Yang H.[1], van Bussel L.G.J.[2], Guilpart N.[1], Van Wart J.[1], Claessens L.[4], Boogaard H.[2], de Groot H.[2], Wolf J.[2], van Oort P.[5]
[1]*Univ. of Nebraska, USA*
[2]*Wageningen University, the Netherlands*
[3]*CSIRO, Australia*
[4]*ICRISAT, Kenya*
[5]*AfricaRice*

14:30 Will sustainable intensification get us to 2 degrees Celsius?

Wollenberg Lini[1], Richards Meryl[1], Havlik Petr[2], Smith Pete[3], Carter Sarah[4], Herold Martin[4]
[1]*CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Gund Institute for Ecological Economics, University of Vermont, USA*
[2]*International Institute for Applied Systems Analysis (IIASA), Austria*
[3]*University of Aberdeen, United Kingdom*
[4]*Wageningen University and Research Centre, the Netherlands*

CONTRIBUTED ORAL PRESENTATIONS

16:30 Climate readiness in smallholder agricultural systems: Lessons learned from REDD+

Zurek Monika, Streck Charlotte, Roe Stephanie, Haupt Franziska with contributions from Wollenberg Lini and de Pinto Alex
Climate Focus, Sarphatikade 13, 1017 WV Amsterdam, the Netherlands

16:45 Assessing low emissions agricultural pathways under alternative climate policy regimes

Kleinwechter Ulrich[1], Havlik Petr[1], Levesque Antoine[1], Forsell Nicklas[1], Zhang Yuquan W.[1], Fricko Oliver[2], Riahi Keywan[2], Obersteiner Michael[1]
[1]*International Institute for Applied Systems Analysis (IIASA), Ecosystems Services and Management Program, Schloßplatz 1, 2361 Laxenburg, Austria*
[2]*International Institute for Applied Systems Analysis (IIASA), Energy Program, Schloßplatz 1, 2361 Laxenburg, Austria*

17:00 Climate-smart coffee systems in East Africa

Jassogne Laurence[1], van Asten Piet[1], Laderach Peter[2], Craparo S.[7], Liebig Theresa[2], Rahn Eric[2], Baca Maria[2], Graefe S.[3], Whitbread Anthony[3], Nibasumba Anaclet[4], Ampaire Edidah [1], Kagezi Godfrey[5], Vaast Philippe[6]
[1]*International Institute of Tropical Agriculure (IITA), P.O.7878, Kampala, Uganda*
[2]*International Center of Tropical Agriculture (CIAT), Cali, Columbia*
[3]*Goettingen University, Goettingen, Germany*
[4]*Institut des Sciences Agronomiques du Burundi (ISABU), Bujumbura, Burundi*

[5]*National Coffee Research Institute (NaCORI), Mukono, Uganda*
[6]*World Agroforestry Centre (ICRAF - CIRAD), Nairobi, Kenya*
[7]*University of Witwatersrand (WITS), South Africa*

17:15 Prioritizing climate-smart agricultural interventions at multiple spatial and temporal scales

Shirsath Paresh B.[1], Dunnett Alex[2], Aggarwal Pramod K.[3], Ghosh J.[4], Joshi Pramod K.[4], Thornton Phillip[5], Pal B.[6]
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[5]*Theme Leader – Data and Tools, CCAFS*
[6]*ISEC, Bengaluru, India*

PARALLEL SESSION L2.4 BREEDING AND PROTECTING CROPS AND LIVESTOCK

KEYNOTE PRESENTATIONS

14:00 Plant breeding for climate-smart agriculture

Glaszmann Jean Christophe
UMR Amélioration Génétique et Adaptation des Plantes (Agap-DDSE), CIRAD, France

14:30 What impact of climate change on animal health?

Lancelot Renaud, Guis Hélène, Lefrançois Thierry
Cirad, INRA, UMR CMAEE, France

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16:30 Reducing nitrogen run-off and emission, and increasing rice productivity in African rice production environment

van Boxtel Jos[1], Selvaraj Michael[2], Dartey Kofi[3], Lamo Jimmy[4], Asante Maxwell[3], Lu Zhongjin[1], Ishitani Manabu[2], Addae Prince[5], Sanni Kayode[5]
[1]*Arcadia Biosciences, Davis CA 95618, USA*
[2]*CIAT, AA6713 Cali, Colombia*
[3]*CSIR- CRI, PO Box 3785, Kumasi, Ghana*
[4]*NARO-NaCRRI, Box 7084, Kampala, Uganda*
[5]*AATF, PO Box 30709, Nairobi, Kenya*

16:45 Utilization of ex situ collections and climate analogues for enhancing adaptive capacity to climate change

Archak Sunil[1], Semwal D.P.[1], Pandey Sushil[1], Mittra Sarika[2], Mathur P.N.[2], Agarwal Pramod[3], Bansal K.C.[1]
[1]*ICAR-National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi 110 012, India*
[2]*Bioversity International, Pusa Campus, New Delhi 110 012, India*
[3]*IWMI, Pusa Campus, New Delhi 110 012, India*

17:00 Adaptation of Mediterranean bovine livestock to climate constraints. Genetic diversity and breeding systems

Flori Laurence[1,2], Moazami-Goudarzi Katayoun[1], Lecomte Philippe[3], Moulin Charles-Henri[3,4], Thévenon Sophie[2], Alary Véronique[3], Casabianca François[5], Lauvie Anne[5], Boushaba Nadjet[6], Saïdi-Mehtar Nadhira[6], Boujenane Ismail[7], Araba Abdelillah[7], Menni Dalal[7], Pineau Olivier[8], Ciampolini Roberta[9], Casu Sara[10], ElBeltagy Ahmed[11], Osman Mona-Abdelzaher[11], Rodellar Clemen[12], Martinez Amparo[13], Delgado Juan-Vicente[13], Landi Vincenzo[13], Hadjipavlou Georgia[14], Ligda Christina[15], Gautier Mathieu[16], Laloë Denis[1]
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[8]*La Tour du Valat, 13104 Arles, France*
[9]*Dipartimenta di Scienze Veterinarie, LBG, 56124 Pisa, Italy*
[10]*Agris Sardegna, Settore Genetica e Biotecnologie, 07100 Sassari, Italy*
[11]*APRI, Animal Breeding and Genetics, Cairo, Egypt*
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[16]*INRA/IRD/Cirad/Montpellier SupAgro, CBGP, 34988 Montferrier-sur-Lez, France*

17:15 Towards genotypes adapted to climate change via combination of phenotyping and modelling: The projects DROPS and Phenome

Tardieu François
INRA, LEPSE, 34060 Montpellier, France

PARALLEL SESSION L2.5 OVERCOMING BARRIERS: POLICIES AND INSTITUTIONAL ARRANGEMENTS TO SUPPORT CSA

KEYNOTE PRESENTATIONS

14:00 Overcoming barriers: policies and institutional arrangements to support CSA

Lipper Leslie
FAO Rome, Via delle Terme di Caracalla, Rome, Italy

14:30 Policies and institutions conducive for enhancing the transfer to CSA in Africa

Sedogo Laurent[1], Lamers John[2], William Fonta[3]
[1]*Executive Director WASCAL Accra, Ghana*
[2]*Coordinator of the Core Research Program of WASCAL, ZEF- University of Bonn, Germany*
[3]*Research Coordinator, WASCAL Competence Center Ouagadougou, Burkina Faso*

CONTRIBUTED ORAL PRESENTATIONS

16:30 Schools as climate smart agriculture information hubs

Manalo Jaime IV A., Layaoen Myriam G., Balmeo Katherine P., Berto Jayson C., Frediles Christina A., Saludez Frederick M.

Development Communication Division, Philippine Rice Research Institute, Maligaya, Science City of Munoz, Nueva Ecija 3119, Philippines

16:45 Advancing CSA solutions through global collaboration: the Global Research Alliance on Agricultural Greenhouse Gases

Clark Harry[1], Scholten Martin[2]
[1]*NZAGRC, Tennent Drive, Private Bag 11008, Palmerston North 4442, New Zealand*
[2]*Wageningen UR, Droevendaalsesteeg 4, 6708 PB Wageningen, the Netherlands*

17:00 Using whole-farm models for policy analysis of climate smart agriculture

Paolantonio Adriana[1], Branca Giacomo[1], Arslan Aslihan[1], Cavatassi Romina[1], Cacho Oscar[2]
[1]*Agricultural Development Economics Division, Food and Agriculture Organization of the UN, Viale delle Terme di Caracalla, Rome 00153, Italy*
[2]*University of New England, Armidale NSW 2350, Australia*

17:15 Climate shocks and risk attitudes among female and male maize farmers in Kenya

Wainaina Priscilla[1], Tongruksawattana Songporne[2], De Groote Hugo[2], Gunaratna Nilupa[3]
[1]*Department of Agricultural Economics and Rural Development; Georg-August-University of Goettingen, Germany*
[2]*International Maize and Wheat Improvement Center (CIMMYT), Nairobi, Kenya*
[3]*Department of Global Health and Population, Harvard School of Public Health, Massachusetts, USA*

POSTER SESSION 2

L2.1 DEVELOPING AND EVALUATING CLIMATE SMART PRACTICES

1. Climate Smart Management Options for Improving the Soil Fertility and Farm Productivity in the Middle Hills of Nepal

Shrestha Shiva KumIar, Shrestha A., Bishwakarma B. K., Allen R.
Sustainable Soil Management Programme (SSMP), HELVETAS Swiss Intercooperation Nepal, GPO Box 688, Kathmandu, Nepal

2. Linking an ecological based system and social resilience to build Climate Smart village model in Niger

Tougiani Abasse[1], Adamou Basso[1], Boureima Moussa[1], Jules Bayala[2] and Robert Zougmore[3]
[1]*Institut National de Recherche Agronomique du Niger, BP429, Niamey, Niger*
[2]*World Agroforestry research Centre, Sahel Node, Samanko, BP: E5118, Bamako, Mali*
[3]*Programme CCAFS Afrique de l'Ouest, ICRISAT PO Box 320 Bamako, Mali*

3. Agriculture, climatic risks and food security in disaster-prone coastal landscape of Bangladesh

Ronju Ahammad
Charles Darwin University, Australia

4. Assessing economic benefits of the use of climate seasonal forecasts within cowpea and sesame sectors in Burkina Faso

Ouédraogo Mathieu[1], Barry Silamana[2], Kagambega Levy[2], Somé Léopold[2], Zougmoré Robert[1]

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[2]Institut de l'Environnement et de Recherches Agricoles (INERA), 04 BP 8645 Ouagadougou 04, Burkina Faso

5. Measurement of climate change and its effect: comparison between an objective method and population perceptions

Azeufouet Alain Simplice[1], Fofiri Nzossie Eric Joël[2], Bring Christophe[2]
[1]Ministère de l'Agriculture et du développement rural / DESA, BP. 294 issea Yaoundé, Cameroon
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6. A set of indicators to evaluate policies for climate smart agriculture

Bonati Guido, Altobelli Filiberto
Istituto Nazionale di Economia Agraria, Via Nomentana 41, 00161 Roma, Italy

7. Developing and evaluating CSA practices at country level: lessons learned from Malawi

Phiri George[1], Lipper Leslie[2], Asfaw Solomon[3], Cattaneo Andrea[4], Cavatassi Romina[5], Paolantino Adriana[3], McCarthy Nancy[6], Spairani Alessandro[7], Branca Giacomo[8], Grewer Uwe[9], Mann Wendy[10]
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8. Developing and evaluating CSA practices at country level: lessons learned from the Zambian experience

Kokwe Misael[1], Lipper Leslie[2], Arslan Aslihan[3], Cattaneo Andrea[4], McCarthy Nancy[5], Spairani Alessandro[6], Branca Giacomo[7], Grewer Uwe[8], Mann Wendy[9]
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[7]University of Tuscia, Viterbo, Italy
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9. Millet and sorghum leaf pruning and transplantation as adaptation techniques to rainfall variability in the Sahel

Alhassane A., Traore S.B., Sarr B., Lawali M. N., Seybou O. A. B, Chaibou B.
Centre Régional AGRHYMET, PO Box 11011, Niamey, Niger

10. CSA menus of practices in the MICCA pilots

Rioux Janie, Rosenstock Todd, Kirui Josephine, Mpanda Mathew, Massoro Erasto, Karttunen Kaisa
Food and Agriculture Organization of the UN, Viale delle Terme di Caracalla, Rome 0015, Italy

11. Sustainability of broiler production in the context of climate change – Evaluation of new incubation strategies

Nyuiadzi Dzidzo[1,10], Méda Bertrand[1], Travel Angélique[2], Berri Cécile[1], Bignon Laure[2], Leterrier Christine[3,4,5,6], Guilloteau Laurence[7], Coustham Vincent[1], Dusart Léonie[2], Mercerand Frédéric[8], Delaveau Joël[8], Grasteau Sandrine[1], Tona Kokou[9], Bouvarel Isabelle[2], Collin Anne[1]

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[2]*Institut Technique de l'Aviculture, F-37380, Nouzilly, France*

[3]*INRA, UMR85 Physiologie de la Reproduction et des Comportements, F-3738, Nouzilly, France*

[4]*CNRS, UMR7247, F-37380, Nouzilly, France*

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[6]*IFCE, F-37380, Nouzilly, France*

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[10]*Institut Togolais de Recherche Agronomique (ITRA), BP 1163, Lomé, Togo*

12. An analytical framework for Climate-Smart Agriculture at the community level

Chandra Alvin, McNamara Karen, Dargusch Paul

School of Geography Planning and Environmental Management, University of Queensland, St Lucia Campus, Brisbane, QLD 4072, Australia

13. Are cropping practices developed by Sub-Saharan farmers climate-smart? Case study of millet cropping system in Senegal

Tall Laure[1], Mbengue Medoune[2], Ndour B. Yacine[1], Masse Dominique[2], Clermont-Dauphin Cathy[3]

[1]*Institut Sénégalais de Recherches Agricoles (ISRA), Laboratoire National sur les productions végétales (LNRPV), Dakar, Senegal*

[2]*Institut de Recherche pour le Développement (IRD), LMI IESOL, Dakar, Senegal*

[3]*Institut de Recherche pour le Développement (IRD), UMR Eco&Sol, Montpellier, France*

14. Namibia specific climate smart agricultural land use practices: a budding vehicle for improving ecosystem services

Kuhn Nikolaus J., Naanda Martha Talamondjila, Bloemertz Lena

Physical Geography and Environmental Change, Department of Environmental Sciences, University of Basel (UNIBAS), Klingelbergstrasse 27, 4056 Basel, Switzerland

15. A two-dimension evaluation of CSA practices. Evaluating practices by indicators and reduce non-observable variable bias

Maldonado Jorge[1], Gómez John[1], Corner-Doloff Caitlin[2], Lizarazo Miguel[2]

[1]*Universidad de los Andes, Bogotá, Colombia*

[2]*International Center for Tropical Agriculture (CIAT), Decision and Policy Analysis, Cali, Colombia*

16. Balancing complexity and usability when modelling farm scale production and greenhouse gas emissions

Hutchings Nicholas, Kristensen Ib

Dept of Agroecology, Aarhus University, Blichers Alle 1, 8830 Tjele, Denmark

17. An impact assessment of distinct agricultural climate protection measures for the implementation on 10 000 Swiss farms

Prechsl Ulrich E., Alig Ceesay Martina, Wolff Veronika, Gaillard Gérard

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18. How biodiversity-agriculture integration meets environmental expectations in a changing climate: a gender perspective

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19. Analysing constraints to the improvement of cattle productivity via trypanosomosis treatment in West Africa

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20. Emission of N_2O from soil received saline and sodic water: effects of compost and gypsum applications

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21. Climate-Smart Agriculture livelihood options for displaced population on Yap Island

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22. Evaluating the cost-effectiveness of development investments

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23. MAPA project: resilient agro-climatic adaptation models for livestock production systems in Boyacá, Colombia

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24. Assessing the determinants of adaptation strategies at farm level: the case of wine growers in South-East France

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25. Determinants of adoption of climate smart agriculture in coastal Bangladesh

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26. Evolution of soil functional diversity after changes in management practices and effects on N_2O emissions

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27. Opportunities and challenges in China's irrigation water–energy nexus

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28. A climate smart strategy to reduce risks and increase resilience of agricultural production systems in Colombia

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29. Interpretation of GHG emissions from mixed crop, grassland and ruminant systems using the FarmSim model

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30. DAYCENT parameterization and uncertainty assessment for modelling Swiss crops

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31. The yield response of intercrop system to rainfall changes on the southern slopes of Mt. Kenya in Embu

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32. Rain water harvest technology as a tool for climate smart agriculture for small holder farmer in Bangladesh

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33. Greenhouse gases emission efficiency of alternative tillage practices in wheat farming systems of Bangladesh

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34. Enabling synergies between development, climate change and conservation through land use practices portfolio approach

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35. Coffee agroforestry systems in Peru – a double dividend for biodiversity and small scale farmers?

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36. Soil carbon input by below- and above-ground biomass in rainfed cropping systems in the highlands, Madagascar

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37. Climate Smart livestock development in natural and improved savannas of an extensive ranch in central Africa (RDC)

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38. Targeting CSA in Southern Tanzania under multiple uncertainties

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39. Opportunities and limitations of emissions intensity as a metric for climate change mitigation from the livestock sector

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40. Climate smart agriculture from field to farm scale: a model based approach for Southern Africa

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41. Mainstreaming climate smart agriculture practices through climate smart villages: scalable evidences from South Asia

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42. Towards a scalable framework for evaluating and prioritizing climate-smart agriculture practices and programs

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43. Repeated inputs of organic matter in the long term protect soils from global changes

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44. The use of agroforestry practices by dairy farmers in Malawi

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45. Towards climate-smart dairy value chains in Tanzania

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46. Adapting pest management practices in sub-Saharan horticultural cropping systems in the context of climate change

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47. Promoting Climate Smart Agriculture in Nigeria: Household strategies and determinants among farmers

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48. Climate forecast, sustainable land and practices management, useful tools for implementation a climate smart village

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49. Characterization of biochar properties derived from willow plant biomass for carbon sequestration and agricultural use

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50. Assessing mitigation potential of agricultural practices in tropical, developing country systems

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51. PERPHECLIM ACCAF Project - Perennial fruit crops and forest phenology evolution facing climatic changes

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52. Potential for biochar to mitigate N_2O emissions is minimal at the field scale and in upland cropping systems

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53. Facilitating climate adaptation in irrigated agriculture with decision support systems: El Molino platform

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54. A model-based approach for adapting cropping systems to climate change

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55. Tweaking the system: optimization of mitigation strategies in smallholder flooded rice systems

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56. Effect of coated and uncoated dietary nitrate on dairy cow health and dairy product quality

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57. Rainwater harvesting and conservation: climate smart sustainable techniques for homestead and cropland production

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58. Pathways for Climate Smart Agriculture (CSA) in the drylands of Africa

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59. Climate-smart agriculture: panacea, propaganda or paradigm shift?

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60. Evaluating agricultural mitigation and scaling up climate-smart practices using the FAO EX-Ante Carbon-balance Tool

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61. Characterization, stability, availability of nutrients and microbial effects of kiln produced biochars

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62. Effect of pyrolysis temperatures on stability and priming effects of C3 and C4 biochars applied to two different soils

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63. Smallholders farm carbon footprint reduced by agroecological practices (Highlands & East Coast, Madagascar)

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64. Climate Smart Agriculture imperative in Nepal: prospect and challenges

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65. Big data from small farms: analysis of drivers of food security across farming systems in sub Saharan Africa

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66. Participatory action research in climate-smart villages of Tanzania: fast track for new potato resilient varieties

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67. Prospects of climate smart agriculture (CSA) under low-input and rain-fed conditions in southern Africa

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68. Climate change, promising technologies and ex ante analysis of impacts on agriculture and food security to 2050

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69. Strategies for developing climate resilient genotypes of rice and chickpea

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70. Simulation of spot blotch in wheat as strategic decision support for adaptation practice in changing scenario

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71. To evaluate reforestation in farms: a tool for smallholders and the sustainability of their initiatives (EvaRefo)

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72. Backyard potted yam cultivation in Abuja, Nigeria

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73. Meta-analysis of the effect of dietary nitrate on enteric methane emissions in ruminants

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74. Climate smart strategies to strengthened coffee farmers adaptive capacity to climate change

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75. Linking agricultural adaptation strategies and food security: evidence from West Africa

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76. Quantifying greenhouse gas emissions and carbon storage at the local scale in the U.S.

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77. A systemic approach to evaluate shea parklands as possible smart agriculture to be intensified in Sudanese Africa

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78. Participatory methodology of agricultural extension to Climate Smart Agriculture development: a case in Brazil

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L2.2 FACING CLIMATIC VARIABILITY AND EXTREMES

79. Consequences of high temperatures and drought on peach fruit production strongly depend on their period of occurrence

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80. Reducing uncertainty in prediction of wheat performance under climate change

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81. Managing climate induced risks and adaptation in the agriculture sector; a case of Punjab province Pakistan

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82. Veille Agro Climatique (VAC): a real time monitoring tool for agroclimatic conditions

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83. Modelling of extreme climate events for South Africa using historical data and general circulation models

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84. Beyond incremental change: transformation to climate-smart agriculture in response to changing extremes

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85. Strengthening the capacity of local extension services to face agroclimatic risks for production systems

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86. Grassland manipulation experiments across climatic zones

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87. Building a global framework for banana resilience and adaptation under increased weather variability and uncertainty

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88. Gauging the effects of extreme climate events on European crop yields

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89. Development of district contingency plans as a coping strategy to face climate variability and extremes in agriculture

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90. Why role of local institution is crucial in Climate Smart Agriculture? Some evidence from rice-wheat system of Nepal

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91. Introducing a legume cover crop in rubber plantations is not necessarily an option for their sustainability in dry areas

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92. Sustainability of the Koga irrigation scheme: adaptive water management to deal with climate variability and change

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93. Pearl millet yields and climate evolution across the last 20 years in central Senegal. A yield gap study

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94. Effective adaptation strategies and risk reduction to increased climatic variability among coffee farmers in Mesoamerica

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95. Impact of climate change on crop production in southern Mali and the potential of adaptation strategies

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96. Use of regional climate model output for modelling the effects of future extremes in agriculture

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97. Drought resistant and resilient plant functional types can maintain production in intensively managed grassland

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98. Phenotypic variation among and within thirty accessions of Onobrychis viciifolia examined under climate change scenarios

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99. Participatory assessment of vulnerability to climate change for improved adaptations to climate smart agriculture

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100. Adaptation strategies for livestock production systems in a changing environment

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101. Impact of climate extreme and variability on agriculture: a case from mountain community of eastern Nepal

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102. Analyses of extreme weather events and its impact to agriculture smallholders in Gandaki River Basin of Nepal Himalaya

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103. Developmental competence and expression pattern of heat shock protein genes in buffalo oocytes during heat stress

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104. Heat tolerance in wheat identified as a key trait for increased yield potential in Europe under climate change

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105. Is livelihood diversification Climate-Smart Agricultural strategy? Micro-evidence from Malawi

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106. Prospering rural vulnerable despite climate change: implications for "Triple Win"

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107. Participatory climate risk management at short-term and seasonal scales – examples from South Asia

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108. Establishment of dynamic-transfer system for agro-climate knowledge and farmers' response

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109. Empirical assessment of climate change on major agricultural crops of Punjab, Pakistan

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110. Perceptions on climate change and impacts on ecosystem services in eastern Africa: implications for policy actions

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111. Irrigation management of salt water: study of potato and pea grown in intercropping with olive in southern Tunisia

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112. Assessment of the variability of yield of maize in Lilongwe district in relation to climate using DSSAT model

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L2.3 COMBINING MITIGATION, ADAPTATION AND SUSTAINABLE INTENSIFICATION

113. Agricultural intensification trajectories and climate smart agriculture in Nicaraguan tropical systems

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114. Value of estimating farm GHG budgets making use of process-based modelling

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115. Farmer's perceptions on climate change and prospects for climate smart agriculture along the tree cover transition curve

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116. The Agritech Water Cluster – Promoting collaboration to manage future water needs of the agriculture sector

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117. Climate change mitigation and agricultural development scenarios for the high plains of Eastern Colombia

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118. Contributing to CSA progress through a national multidisciplinary research program on adaptation to climate change

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119. Could agroforestry be a way to limit soil erosion susceptibility under a temperate climate?

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120. Scientific and policy recommendations for climate smart arable agriculture in Europe: lessons from the past decade

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121. Adaptation to climate change through land-use change in France and implications for greenhouse gas emissions

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122. Mitigating GHG emissions from ruminant livestock systems

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123. Global assessment of technological innovation for climate change in developing countries: opportunities and challenges

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124. Synergies and trade-offs of adaptation and mitigation on dairy farms

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125. Land management practices as a coping mechanism to frequent and prolonged drought spells by smallholder farms

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126. Sustainable intensification of global maize cropping systems: balancing yield increase and nitrous oxide emissions

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127. Temperature impact on CO_2 emissions and nutrients availability in Malagasy soils under different farming practices

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128. The synergies of fertilization on carbon sequestration and food security in China

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129. Adaptation to climate variability: evaluation of adaptation tools for the agricultural sector in Guanacaste, Costa Rica

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130. Efficiently mitigating climate change through improved land management in smallholder agriculture of Malawi and Zambia

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131. Climate-Smart water and nitrogen management strategies for lowland rice

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132. Storing C in agricultural soils: evaluating triple-win climate-smart actions for France

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133. Innovative cropping systems under GHG emissions constraint: results of a long-term field trial assessment

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134. Contribution of agroforestry to livelihoods and climate change mitigation in Western Kenya

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135. Alternative water management minimizes greenhouse gas emissions from rice systems while maintaining yield

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136. Climate mitigation: trade-offs between agricultural product carbon footprints and land use intensity

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137. Integrated fertiliser microdosing and organic manure to adapt to climate variability and change in Northern Benin

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138. The Global Yield Gap Atlas for targeting sustainable intensification options for smallholders in Sub-Saharan Africa

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139. Impacts of agricultural diversity on self-sufficiency for forage, feeding costs and GHG emissions in dairy systems

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140. Water resources transfers through southern African food trade: resource efficiency and climate adaptation

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141. Municipal solid waste composts as organic inputs in vegetable gardening cropping systems in Mahajanga, Madagascar

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142. Evaluating the impact of rising fertilizer prices on crop yields

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143. Agent based model analysis on the impact of agricultural land-use change adaptation in semi-arid Ghana

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144. The gathering of Non-Timber Forest Products as adaptation strategy to climate change in the rural community of Niaguis

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145. Optimisation of the nitrogen fertilisation in the context of climate change

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146. Climate change impacts on crops production and adaptive measures from farmers' perspective in North-East China

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147. Emissions mitigation by sustainable intensification in Brazilian livestock production

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L2.4 BREEDING AND PROTECTING CROPS AND LIVESTOCK

148. Adaptation of tropical cattle breeds to their environment, in the perspective of climatic change

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149. Genetic diversity of Dactylis glomerata in the response to temperature during germination

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150. Globally representative C. arabica variety trial site selection in a changing climate

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151. "ReColAd": Collaborative network on farm animal adaptation to environmental changes

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152. Crop diversity as an adaptation strategy to climate change in West Africa

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153. Genetic variability and phenotypic characterization of thermotolerance in rainbow trout

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154. NGS for identifying wild-to-cultivated gene flow for African crops adaptation

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155. Impact of pea genetic variability on the control of N_2O reduction by soil-microorganisms-plant systems

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156. Using crop-climate models for designing climate-smart breeding strategies

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157. Genetics of tolerance of extra-early Quality Protein Maize inbreds under contrasting environments

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158. Adaptation of alfalfa ecotypes to climate change

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159. Improvement of yield and related characters of temperate maize (Zea mays L.) under three water regimes

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160. Breeding for sunflower hybrids adapted to climate change: the SUNRISE collaborative and multi-disciplinary project

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161. Climate change in tropical environment: what impact on agricultural pests and diseases? What crop protection strategies?

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162. Understanding the genetic diversity of Ethiopian oilseed Noug (Guizotia abissinica) for its improvement and conservation

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163. Proteomics in the drive for climate smart livestock production

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164. Bridging landscape genomics and quantitative genetics for a regional adaptation of European grasslands to climate-change

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165. Ecological niche of R. fistulosa in climate change context: what future for lowland rice production in West-Africa?

Zossou Norliette, Gouwakinnou Gérard, Idelphonse Sode, Sinsin Brice
Laboratories of Applied Ecology, Faculty of Agronomics Sciences, University of Abomey-Calavi, Benin

166. Effects of heat stress and sulfur restriction during seed filling on grain characteristics in rapeseed

Brunel-Muguet Sophie[1,2,3], D'Hooghe Philippe[1,2,3], Bataillé Marie-Paule[1,2,3], Larré Colette[4], Kim Tae-Hwan[1,2,3,5], Jacques Trouverie[1,2,3], Avice Jean-Christophe[1,2,3], Etienne Philippe[1,2,3], Dürr Carolyne[6]
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167. Selection of families new of rice for their adaptability of lowland in West Africa

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168. Evaluation of triticale genotypes for food and feed security in Egypt
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169. Improving Bambara groundnut for global food security: MAGIC populations for ideotype development and genomic analysis
Aliyu Siise[1,2,3], Kendabie Presidor[1, 2], Murchie Erik[1], Massawe J. Festo[2] , Mayes Sean[3]
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170. Genetics in controlling small ruminant's internal nematodes infestation in the era of climate change
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171. Climate change impact on incidence of mite (Tetranychus urticae Koch) infesting ladysfinger in sub-Himalayan India
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L2.5 OVERCOMING BARRIERS: POLICIES AND INSTITUTIONAL ARRANGEMENTS TO SUPPORT CSA

172. Cross-scale policy dynamics and climate smart agriculture
Crane Todd, Robinson Lance
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173. Theory and criteria for improved understanding of Climate Smart Territories (CST)
Jenet Andreas[1], Van Etten Jacob[2], Sepulveda Claudia[1], Martinez-Salinas Alejandra[1,3], Villanueva Cristobal[1], Sanabria Oscar[1], Louman Baastian[1], Alpizar Francisco[1]
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174. Scenario-guided policy development and investment for Climate Smart Agriculture in Cambodia

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175. Effects of the Jordanian rainfed barley-livestock producer perceptions and values on their adaptation to climate change

Auerbach Anita[1], Yigezu Yigezu[2], Haddadin Maissa[2], El-Shater Tamer[2], Akroush Samia[2], De Pauw Eddy[2], Guendel Sabine[1]

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176. Climate Smart Agriculture in the Northeast: assessing stakeholders' belief-action gaps and research/extension capacity

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177. Barriers to the adoption and diffusion of CSA technological innovations in Europe

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178. Necessity of clear concepts and convergence of discourse for a climate-smart agriculture (Costa Rica)

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179. A rights-based approach to realizing socially equitable development outcomes from climate smart agriculture

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180. Implications of alternative GHG emission metrics for emission trends and targets

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181. Climate smart agriculture without climate smart spatial planning?

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182. Forestry and agriculture in the climate change governance: Non-UNFCCC venues for enhancing action

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183. Barriers to uptake of conservation agriculture in Malawi: multi-level analyses & development planning implications

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184. Policies for climate-smart agriculture: contribution of agroforestry literature

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185. Learning and sharing for action: experiences of Ghana climate change and food security platform

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186. Linking climate change adaptation and mitigation: Implications for Central America

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187. Social learning in support of CSA: getting to outcomes and impact

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188. Policy instruments for Climate Smart Agriculture: toward a specific integrated analytical framework

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189. Building local capacity in agricultural carbon projects in Kenya and Uganda through participatory action research

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190. What does it take to see transformative adaptation? Evidence from sub-Saharan Africa

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191. Is technical information what policy makers need to take action on the climate change adaptation of smallholder farmers?

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192. Drip irrigation works: drip irrigation kits do not

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193. Barriers to adaptation and mitigation to climate change in livestock farms of Africa, South America and Europe

Frey Hélène[1], Vayssières Jonathan[1], Messad Samir[1], Koslowski Franck[2], Stienezen Marcia[3], Cardoso Viera Paulo[4], Poccard René[1], Blanchard Mélanie[1], Silvestri Silvia[5], García de Jalón Silvestre[6], Lecomte Philippe[1]
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ORAL PRESENTATIONS

Parallel session L2.1
Developing and evaluating climate-smart practices

Tuesday, 17 March 2015

14:00–18:00

ROOM SULLY 1

KEYNOTE PRESENTATIONS

14:00 Developing and evaluating climate-smart practices and services

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While the concept of climate-smart agriculture (CSA) is new, it draws on concepts that have been around for a while, such as sustainable agriculture and sustainable intensification. In simplest terms, CSA emphasises the climate dimensions – both adaptation and mitigation – of previous concepts, suggests shifts in priorities for investment and implementation, and gives greater prominence to certain partnerships (Campbell *et al.*, 2014; Lipper *et al.*, 2014).

Rosenstock (*et al.*, in prep.) have examined 6000 peer-reviewed papers to compile the productivity, adaptation and mitigation outcomes of agricultural practices, so as to identify the "smartness" of CSA practices. They find numerous trade-offs amongst the dimensions of CSA. They also record a dearth of studies that examine all three stated outcomes of CSA, suggesting a new paradigm for research. This work has led to the Compendium of CSA Practices.

Other literature on specific practices (*e.g.* alternate wetting and drying in rice, conservation agriculture) shows how context-specific outcomes are; being highly dependent on the agroecological conditions (Sander *et al.*, in prep.; Powlson *et al.*, 2014).

A third area of work shows how socio-economic factors influence uptake of practices and services (e.g. Beuchelt and Badstue, 2013). For example, intensity of adoption of conservation agriculture is negatively affected by land per capita – an indicator of labour constraints (Arslan *et al.*, 2013). Women are less likely to be targeted or involved in climate information services and are even less likely to receive and use such services (McKune *et al.*, in prep.).

Put together, this work suggests that we have to recognise levels of climate smartness for specific objectives, agro-ecologies and socio-economic conditions. The global community has indicated a willingness to ensure rapid progress in making agriculture climate-smart, but the above conclusion – that CSA is highly context-specific – does not help policy makers, investors and implementing agencies make easy decisions about what should be incentivised and implemented. For this to happen, we propose "CSA-Plan" – a set of planning and implementation tools. This is now being tested and developed in several countries across Latin America, Africa and Asia, and with the Vision 25 x 25 initiative of the New Partnership for Africa's Economic Development's (AU-NEPAD).

CSA-Plan consists of four steps: Situation Analysis; Targeting and Prioritising; Programming Design; Monitoring and Evaluation. These are flexibly applied depending on context, and can be applied at any level, from community to regional economic block. A key principle is stakeholder engagement at all steps.

Situation Analysis includes understanding the context in which the CSA concept is being applied and identifying entry points for investing in CSA, usually through use of existing global and national data sources and expert input including farmer participation. Key tools here are the Compendium of CSA Practices, vulnerability analysis and institutional analysis. The results of this step can be in the form of a Country Profile (or project profile), where entry points related to agricultural priorities, institutions, policies and finance are identified, covering technologies and practices, climate information services, and climate-linked advisories and safety nets.

Targeting and Prioritising supports the selection and prioritisation of investment portfolios. This sets the scope (e.g. sites, types of climate changes to address, transformative actions needed), identifies practices, services and policies linked to scope, identifies outcomes of importance to evaluate (indicators) and desired balance of the three CSA goals. A variety of tools are available: Compendium, CSA Practice Briefs, mitigation optimization tool. Stakeholder engagement leads to the shortlisting of priority CSA practices, services and policies. More detailed analysis of the top options, including cost-benefit analyses, analysis of trade-offs, follows. Further stakeholder engagement with key stakeholders, including men and women farmers, helps derive the investment portfolio.

The Programming Design step includes the detailed spatial targeting of implementation activities, including a landscape analysis, barriers and constraints analyses, and assessing the business case for programs and their scaling up. It is supported by a CSA Toolbox (that includes practice guidelines).

The Monitoring and Evaluation step is fraught with challenges, *e.g.*, adaptive capacity and resilience are not easy to operationalise and emissions measurements are extremely expensive and not easily captured by proxies. Some practical suggestions are made for simple ways to monitor and evaluate CSA programmes. The M&E is constructed to promote adaptive learning.

CSA shows much promise, with a wide range of stakeholders acknowledging the need to move rapidly to climate-proof agriculture. As researchers, we can support that process through deep engagement in implementation initiatives.

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14:30 Evaluating agricultural mitigation and scaling up climate-smart practices using the FAO EX-Ante Carbon balance Tool

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The quantification of agricultural greenhouse gas (GHG) emissions is an important component of the Climate Smart Agriculture (CSA) agenda, and a key step in managing and ultimately reducing those emissions in a cost-effective manner. The scale and speed of climate change requires considerable investment in filling knowledge gaps and in research, for the development of time and cost-effective decision-support tools to prioritize both adaptation and mitigation actions, in addition to increasing productivity. The EX-Ante Carbon-balance Tool (EX-ACT) is a land-based accounting system for estimating and projecting changes in the carbon balance over time. The carbon-balance is defined as the net balance from all greenhouse gases (CO_2, CH_4 and N_2O) expressed in CO_2 equivalent that were emitted or sequestered due to the implementation of an action or project as compared to a business-as-usual scenario. EX-ACT can provide ex-ante (as well as ex-post) assessments covering crop intensification, agroforestry, silvopasture, livestock development, perennial agriculture, watershed management, forestry development, and land rehabilitation. It is interactive, user-friendly, and flexible in terms of requirements for coefficients and site-specific data. While EX-ACT is primarily used for project design, it is readily scalable to program, sector-wide, and policy analyses. EX-ACT analyses have been carried out in over 50 countries on climate-smart investment projects worth more than $5 billion dollars. EX-ACT has proven useful in estimating the GHG-balance of such investments and in scaling up climate-smart practices.

CONTRIBUTED ORAL PRESENTATIONS

16:30 Rain water-based integrated agricultural system: a model for ensuring food security and adaptation in coastal Bangladesh

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The coastal areas of Bangladesh face challenges to sustaining agriculture, food and nutrition security in the presence of climate change impacts (*e.g.*, rising sea level, increased salinity, coastal erosion), natural calamities (*e.g.*, cyclone, storm surges, floods, riverbank erosion, drought), and human interventions, creating a situation in most of the coastal areas in which agricultural development, food security, nutrition and livelihood indicators are far worse than national or even rural averages. To adapt to the changing environment and ensure food security, some farmers in the coastal areas have started rain water/fresh water-based integrated (rice + shrimp + vegetable) agricultural systems. This agricultural system raises many questions, including what are the sustainability features of this agricultural practice and how does it help in adaptation and ensuring food security. To assess the sustainability and adaptability of this agricultural system, this study compares them with rice-based and shrimp-based agricultural systems. A holistic and interdisciplinary approach is applied to assess sustainability questions by evaluating both primary and secondary data from the southwest coast of Bangladesh. Primary data were collected through questionnaires, surveys and key informant interviews. The collated data were analyzed using various statistical techniques including measuring yield (t/ha), yield of protein and energy, energy use efficiency, Shannoa diversity index, weighted average, and goalpost value. The findings show that integrated agricultural systems have the capacity to produce more food, maintain biodiversity, ensure ecosystem health and ensure a higher quality of life for farmers than other agricultural systems in the coastal areas of Bangladesh. This system is a unique way to adapt to climate change since it stores rain water for agriculture by protecting the land from surface saline water. It is an example of doing agriculture in a smart way to adapt and ensure food security.

Acknowledgement: This project is supported by SSHRC, Canada

16:45 Additive impacts of climate-smart agriculture practices in mixed crop-livestock systems in Burkina Faso

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Smallholder farmers of Northern Burkina Faso have important development opportunities, but they will have to cope with the effects of climate variability and change. In four farms representative of the area, crop and animal production, income and food security indicators have been simulated, with all combinations of four interventions: i) Optimized crop residue collection; ii) Improved allocation of existing feeds, iii) Crop fertilization; iv) Animal supplementation. The modeling framework we used is based on three existing dynamic livestock (Livsim), crop (Apsim) and household (IAT) models. To assess the impacts of climate variability, a 99 years current climate series has been generated with the climate generator Marksim. The simulations show that collecting crop residues improves significantly the food security indicator (FS) in one farm because it enables the development of cattle production (FS +135%), whereas the effects are moderate in the three other farms (FS <10%). Low amounts of fertilizer have a significant effect (FS +15%), but the simulations show decreasing yield returns and the higher downside risk in the bad years. Improved feed allocation strategies with available resources have a positive effect (FS +9%), which is as important as supplementation with additional feeds. The impacts of the tested interventions are additive and synergistic, because increased crop residues production with fertilization creates opportunities for optimized feeding. As a consequence, in the four farms, the highest income and kilocalorie production (up to 53% compared to current farmer practices) are obtained with a combination of interventions enhancing synergies between the crop and the livestock systems. The household yearly probability to be food secure also increases by up to +26%, suggesting an increased resiliency toward climate variability. We conclude that the best options for adapting mixed crop-livestock systems might be found in the synergies between their components, rather than in single interventions.

17:00 Developing indicators for Climate-Smart Agriculture (CSA)

Rawlins Maurice Andres, Heumesser Christine, Emenanjo Ijeoma, Zhao Yuxuan, Braimoh Ademola

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CSA has emerged as a framework for developing and promoting agricultural systems which simultaneously improve productivity, resilience to climate change, and provide GHG mitigation benefits. However, the implementation of CSA raises several questions including 'what is the climate-smartness of an agricultural technology in a specific context', 'to what extent is an intervention achieving the goals of CSA', and 'is there an enabling environment within a country for CSA implementation'? In response to these questions, the World Bank in collaboration with international partners has developed three indicator sets to support CSA implementation at the national and sub-national levels. The CSA-Policy indicators assess the enabling environment *i.e*. policy and institutional frameworks, and services and infrastructure, within a country supporting the implementation of CSA. The CSA-Technology indicators provide an ex-ante assessment whether agricultural technologies, when applied in different contexts, achieve the goals of CSA. The CSA-Results indicators monitor short-term results of a CSA intervention which may relate to food security, poverty reduction and sustainability. For each indicator set, an index was developed to capture the climate-smartness of each area, *i.e.* technologies, a country's enabling environment, and project level interventions, in a single number. The indicators were developed through a consultative process with international experts on agriculture, rural development and climate change. The major steps in the methodology included: (i) development of a CSA impact pathway and theory of change; (ii) selection of indicators using a set of established criteria; (iii) indicator scoring and aggregation using binary and Likert scoring and fuzzy logic methods; and (iv) testing of indicators using data from World Bank projects, and government documents. The indicators will guide CSA investment decisions, and assist national governments, agricultural specialists and natural resource managers in evaluating the productivity and climate benefits of sustainable land management operations.

17:15 Towards metrics to track and assess climate smart agriculture

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To inform decision-makers, the impact of interventions and progress of climate smart agricultural practices need to be assessed and possible out-scaling options and trade-offs made explicit. For this purpose a stakeholder-based methodology is developed in which the goals and aspirations of the stakeholder are the main entry point. The anticipated effects of the interventions or practices applied by the stakeholder to reach their goals are assessed using indicators addressing food productivity, climate resilience and GHG emissions. The selected indicators will link to existing monitoring systems. For distinct cases of rainfed arable systems in sub-Saharan Africa the methodology is tested at the household and regional level. Starting from the farmers' objectives to obtain a livelihood from agriculture several strategies, including cropping intensification, diversification and increasing farm size, are assessed. The long-term impacts on productivity, climate resilience and GHG emissions are calculated using a farm systems model. The GHG emissions are based on local emission factors when available or when necessary IPCC emissions factors. Long-term climate resilience is determined by estimating the impact of climate change on variations in crop yields and by assessing differences in food self-sufficiency and income via comparison of current yield levels and simulated water-limited yield levels using historical weather data and projected changes in temperature and precipitation up to 2050. First results reveal that less than 50% of the households succeed to escape from poverty using the most intensive crop production strategy. Trade-offs between production increase and GHG emissions associated with applying fertilizers as part of the intensification strategy occur. Depending on the strategy the increase in crop productivity outpaces the increase in GHG emission resulting in a lower GHG emission intensity.

Parallel session L2.2
Facing climatic variability and extremes

Tuesday, 17 March 2015

14:00–18:00

ROOM SULLY 2

KEYNOTE PRESENTATIONS

14:00 Facing climatic variability and extremes

Zougmoré Robert[1], Rao K.P.C.[2], Diedhiou Arona[3]

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Climate change will continue to have far-reaching consequences for agriculture that will disproportionately affect poor and marginalized groups who depend on agriculture for their livelihoods and have a lower capacity to adapt. For instance, rain-fed agriculture will remain vital for food security in sub-Saharan Africa, where nearly 90% of staple food production will continue to come from rain-fed farming systems. Factors like farm productivity, crop, market and local preferences, capacity to invest, willingness to take risks and soil quality play an important role, but climate variability and climate extremes will induce crop failures, fishery collapses and livestock deaths, causing economic losses and undermining food security. These are likely to become more severe as global warming continues.

Historical statistical studies and integrated assessment models provide evidence that climate change will affect agricultural yields and earnings, food prices, reliability of delivery, food quality, and, notably, food safety. Recent AR5 show that global warming is faster than expected and point out the increasingly adverse role of higher temperatures irrespective of rainfall changes. It is shown for example that when warming exceeds +2°C, negative impacts caused by temperature rise in reducing crop yields over West Africa cannot be counteracted by any rainfall change (wet or dry). In this new context, these changes in the minimum and maximum temperature, in the daily thermal range and in the occurrence of heat waves could affect flowering, agricultural production and food security, human health and the demand and cost of energy.

The occurrence of more extreme events have already been observed in many regions of the world (*e.g*. West Africa, Asia) including strong wind, heavy storms, and floods. Climate change impacts on agricultural supply chains also involve uncertainties, interactions, nonlinearities and tipping points. Low-income producers and consumers of food will be more vulnerable to climate change owing to their comparatively limited ability to invest in adaptive institutional systems and technologies under increasing climatic risks. In rural areas, climate changes have immediate and direct effects on the health and well-being of millions of households that depend on natural resources for their basic livelihoods. Smallholder farmers, already struggling to cope effectively with the impacts of current rainfall variability, will face a daunting task in adapting to future climate change. Predicting the exact rate, nature and magnitude of changes in temperature and rainfall is a complex scientific undertaking and there currently remains considerable uncertainty with regard to the final outcome of climate change and its impacts. Uncertainties of climate predictions at local and regional scales are a critical issue of understanding risks, especially with regard to implications for food security. Indeed, insuring food security for the projected 9 billion people in 2050 requires radical transformation of agriculture over the next four decades, growing more food without exacerbating environmental problems and simultaneously coping with climate change.

Responses need to come quickly, with salient and tailored risk management strategies that can limit disasters on agricultural productions and infrastructures. Thus, the need to develop adaptation and transformation strategies, increase the resilience of farming systems and design coping strategies becomes a must. A better knowledge of how local actors such as farmers already adapt to climate variability and extreme weather conditions such as droughts and floods is essential to design new adaptation strategies that can be adopted and used. This should encompass climate-smart planning, management and recovery approaches that will enable farmers to reduce their vulnerability to climate induced risks and shocks, increase their investments on improved management practices, enhance productivity and profitability of agricultural enterprises and become more resilient. In addition to adaptation technologies and practices, options that assist in enhancing farmers' ability to withstand these occasional climate shocks deserve better attention. Better management of surplus production from good seasons, developing community-based safety net programs and diversifying sources of income are possible interventions that can positively contribute to building farmers' ability to manage climate-related shocks. In India for instance, national index insurance programmes have reached over 30 million farmers through a mandatory link with agricultural credit and strong government support.

Also, innovative approaches for communicating risks and uncertainties to all stakeholders, notably decision-makers and farmers, need to be investigated. Improved access to climate information, blending and sharing indigenous and scientific knowledge as well as facilitating dialogue between stakeholders, will contribute making climate-smart all the best practices of agricultural production and management systems. This is for instance the case in Senegal where seasonal climate forecasts, communicated in accessible and meaningful ways to farmers, provide invaluable knowledge for local agricultural decisions and livelihoods. This approach aims to translate and communicate the seasonal forecast, and an indication of its probability, in easily understandable language, giving farmers the capacity to make informed farm management decisions. This is coupled with discussions on farmers' traditional forecast practices, providing space to share the different types of knowledge and thus increase everyone's ability to make informed choices and good decisions. Likewise, advisories shared widely to farmers in Colombia allowed yielding good outcomes of climate risk management.

Considering the progressive nature of climate change, uncertainties associated with predicting changes in rainfall and the need to prepare for both positive and negative potential futures, there is a need to develop climate change adaptation programs that are customized for different regions and climatic conditions focusing on options that make best of variable and changing climatic conditions. The involvement of farmers, policy-makers, researchers, the private sector and civil society in the research process is vital. Successful mitigation and adaptation will entail changes in individual behavior, technology, institutions, agricultural systems and socio-economic systems. These changes cannot be achieved without improving interactions among scientists and decision-makers at all levels of society, especially when the foremost priority is to achieve food security now and in the future.

14:30 Rainfall modifications in the context of climate change: the puzzle of the tropical regions

Lebel Thierry, Vischel Théo

LTHE, IRD & Université de Grenoble, BP 53, 38041, Grenoble Cedex 9, France

The water cycle is a key element controlling the Earth climate. Evaporation and condensation of water are two major processes redistributing the excess of incoming solar energy arriving in the inter-tropical band towards the mid-latitude and polar regions. Water is also at the heart of the vulnerability and risk implications of climate change, as treated in the report of Working Group II of the IPCC. Unfortunately the uncertainties regarding the modifications of the hydrological cycle in a global warming context are as large as these implications. The various components of the water balance are extremely variable in time and space over a broad range of scales, due to the complex interaction between numbers of processes ranging from cloud microphysics to soil moisture transfers, through convection, plant transpiration and root extraction, aquifer drainage, not to mention the oceanic processes. These processes are not equally well represented in climate models, both for scale gap reasons and physical complexity. Consequently the predictions of climate scenarios regarding possible changes in the hydrological cycle may change significantly from one model to another, depending on the regions considered. For instance, there is an agreement that the arid and semi-arid regions under the influence of the descending branch of the Hadley cell will become drier and that this dry area will extend further poleward. Many models also forecast more intense rainfall within the Inter Tropical Convergence Zone (ITCZ), due to a warmer and wetter atmosphere. On the other hand, there is no consensus regarding the evolution of the dynamics of the monsoon systems. Consequently, the future of rainfall in South Asia and in West Africa is pretty much unclear, while these regions are among those which will witness the largest population increase over this century. The challenge for the scientific community is thus threefold. One is of course to improve our understanding of the scale and process interactions in the monsoon systems in order to better represent them in the climate models. There might well be some intrinsic limitation in this improvement, which means that a second major task is to better characterize the present rainfall patterns in tropical regions and their recent evolutions. This is clearly essential in order to study the major bias in the models as well as to detect possible premises of durable changes. Long-term observing systems are a key tool in support of this monitoring and detection work. The third challenge is to use the finer knowledge acquired on the multi-scale rainfall patterns in tropical regions to study their impact on hydrology and agriculture. Apparent contradictions may exist between the local vision of rainfall variability and the regional vision built from analyzing multiscale data sets. It is thus extremely important that communities of scientists working at different scales for different purposes have opportunities to exchange on their findings and questions on multiscale rainfall variability in the Tropics. This is illustrated in the following by looking in more details to recent advances regarding rainfall variability patterns in West Africa.

A comprehensive study of the 1970-1990 drought that affected the whole of West Africa has led to some key findings on the changes of rainfall regime between the wet period 1950-1970 and the ensuing dry period. First of all, in absolute value, the rainfall deficit was relatively homogenous over the whole sub-continent, averaging around 200 mm per year; this means a relative deficit of more than 50% in the northern Sahel and a deficit in that may have not exceeded 15% in the humid coastal areas. Looking at finer scale, it was found that this reduced annual total, was mostly explained by a diminution of the number of rainy events rather than by a diminution of the intensity of the rainfall events. A third major finding was related to the modification of the seasonal cycle associated with the drought. While at the time a link was often assumed between dry years over the Sahel and a reduced length of the rainy season, it was shown that, in fact, dry years were rather characterized by longer and more frequent dry spells at the heart of the rainy season. South to the Sahel, the second rainy season proved to be more affected than the first one. This has important implications for both climate science and agriculture. From a climate perspective it means that this not so much a different positioning of the ITCZ that may be the cause of the 1970-1990 drought, but rather the capacity of triggering convection. As for agriculture, it means that it might be as important for food security in the Sahel, to look for varieties able to resist to dry spells at the heart of the growing period as to try developing short cycle varieties. And in Sudanese regions crops growing during the second rainy season are especially at risk.

In the 1990s, the regional rainfall pattern underwent another major change. Better rainfall conditions returned to the Sudanese domain, while the drought continued unabated in the Sahel. This continued drought was still associated with a persisting reduction of the number of rainy events. This dipole situation (more or less normal rainfall conditions in the South and drought in the North) is not properly seen in climate model simulations, which feeds the discussion about the respective roles played by a warming ocean, on the one hand, and a devegetated continent, on the other hand, in shaping regional rainfall patterns in West Africa.

The 2000s have seen the emergence of yet another configuration. Rainfall returned to better rainfall conditions over the Central and Eastern Sahel, while it remained highly in deficit over the Western Sahel. This East-West dipole is seen in the recent CMIP simulations, corresponding to changes in both the Hadley cell and the Walker cell linking the Asian monsoon to the African monsoon. Models anticipate that this pattern will dominate for the decades to come. At the same time, a significant increase of extreme rainfall events is detected, starting at the beginning of the 2000s, explaining the more frequent occurrence of inundations all over the Sahel. The return to higher annual rainfall in the Central Sahel happens in a context of persisting deficit of the number of rain events, compensated by a larger share of strong rainfall events. This new rainfall regime is typical of a more extreme climate characterized by harsher dry spells during the rainy season and more extreme rainfall events, raising puzzling questions for both the climatologists and the agronomists. The first will pursue their quest for reproducing this behavior in their models, while the seconds must ponder the implications for cropping.

CONTRIBUTED ORAL PRESENTATIONS

16:30 The potential for underutilised crops to improve food security in the face of climate change

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Food production must be increased to respond to the demands of a growing world population and the challenges posed by climate change. Higher temperatures, unpredictable rainfall and weather patterns, changes in growing seasons, increased occurrences of drought and extreme weather events will exert a greater strain on agriculture. Emerging evidence suggests that climate change will cause shifts in food production and yield loss due to more unpredictable and hostile weather patterns.

A key strategy to adapt to a changing climate is the development and promotion of underutilised crop species. The world today relies on a small number of crop species for food, mainly major cereals (wheat, rice and maize), leaving an abundance of genetic resources and potentially beneficial traits neglected. Exploiting the large reservoir of minor and underutilised crop plants would provide a more diversified agricultural system and food sources necessary to address food and nutrition security concerns in the face of climate change. Underutilised crops (also known as understudied, neglected, orphan, lost or disadvantaged crops) play an important role in food security, nutrition, and income generation of many resource-poor farmers and consumers especially in the developing world.

Using specific crop examples, we discuss the potential for underutilised crops to improve food and nutrition security, increase agricultural diversification and minimise environmental degradation. We present research evidence to suggest that crop specific traits and physiological responses contribute to underutilised crops resilience in the face of climate change. We urge that in the semi-arid environments these traits and physiological responses contribute significantly to crops ability to endure periods of water stress. We conclude that a key mitigation strategy to minimise the impact of climate change on crop production must be through the development of underutilised crops with proven potential to cope with the adverse effects of climate change.

16:45 Changes in climate variability and potential for impacts of droughts on agricultural markets

Leclère David, Havlík Petr

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The effects of expected future changes in climate on agriculture have long been studied but remain largely uncertain. Recently, collaborative efforts in the agricultural modelling community have conducted inter-comparisons of simulated outcomes across main global modelling framework, in particular through the ISI-MIP and AGMIP projects. This led to an improved understanding of long-term climate change related outcomes in the food global system, potential adaptations, and the uncertainties at stake. However, little is known about the risks for the agricultural sector of changes in climate inter-annual variability.
Here we use the spatially explicit global scale crop yield simulations generated with the EPIC crop model in the frame of the above mentioned projects for a range of nine climatic scenarios, four crops under rainfed low- and high-fertilization as well as irrigated high-fertilization managements. We compare the estimated present and future yield variability, and develop a few metrics to estimate the potential impacts at market level of drought events, for the different climate change scenarios. In particular we develop statistical methods to estimate at high resolution places subject to drought, and then incorporate information on current land use to scale-up the intensity and severity of drought events with respect to their extent and impact on national productions levels, as an indicator of potential for market-level impacts.

17:00 How precisely do maize crop models simulate the impact of climate change variables on yields and water use?

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AgMIP is an international program bringing together research projects on climate, crop modelling and regional agriculture adaptation to climate change. One objective is to better assess the projections of global food availability depending on different staple crops (wheat, rice and maize), taking into account the projections of climate change for the end of century and the uncertainty attached to them. The need for robust estimates, *i.e.* good crop models for yields and use of natural resources is a prerequisite to benchmark the various cropping systems and local solutions that will ultimately be explored in order to cope with climate change, without bringing about any negative side effects on the environment. Modelers hence work together internationally in order to compare and improve process-based crop simulation models. Maize is a strategic crop, exhibiting high potential radiation and water use efficiencies and is cultivated worldwide. In a first phase, the impacts of CO_2 and temperature on the maize yields and water use were studied using 23 crop models on 4 sites with contrasted cool or hot climate conditions, under no water limitation (Lusignan in France, Ames in the United States, Morogoro in Tanzania and Rio Verde in Brasil). Models were run using local soil conditions and climate variables for 30 years (1980-2010) after adjusting the cultivar parameters to the ones used in one experiment in each site. At the four sites studied, the average values across models of simulated yields were closer to the observed local experimental results than the simulation of any individual model. This indicated that ensemble modelling could be a relevant way to approach the impact of climate change on maize yields. There was also a broad agreement between models to simulate a reduction in maize yield in response to temperature, roughly - 0.5 Mg ha^{-1} per °C increase, with no significant impact on water use, although the latter variable was estimated with a large variability between models. Plant phenology was the mostly altered process with increasing temperature. Shortening of the duration from flowering to maturity in particular reduced the gain in grain weight during that phase. This suggests that genetics could hence play a key role in adapting maize production to climate change, at least under high water availability. Doubling [CO_2] from 360 to 720 µmole $mole^{-1}$ increased grain yield by 7.5% on average across models and sites, with a slight decrease of water use, bringing about an increase in water use efficiency. However, the variability of the response to [CO_2] was very high, bringing about the need to better simulate the role of CO_2, especially on plant transpiration. In a second phase, models are therefore now being tested against Free Air CO_2 Enrichment experimental data, so that variability can be reduced and the actual impact of global change on water use can be assessed with a relevant precision to adaptating agricultural practices.

17:15 Modeling livestock production under climate constraint in the African drylands to identify interventions for adaptation

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In the African drylands, livestock is the main source of food, income and livelihood for millions of pastoralists and agro-pastoralists who are very vulnerable and exposed to climate change. Our understanding of livestock contribution to food security and rural development as well as climate change adaptation issues in these areas is still quite poor and limits our capacity to guide interventions for building resilience.

This paper presents a modelling framework for livestock productivity under climate constraints. It is the result of a collaboration between FAO, CIRAD, IFPRI and Action contre la Faim (ACF), for a contribution to the World Bank study on the economics of resilience in the African drylands. The methodology relies on the integration of four models and a participative interaction with local livestock experts: biomass availability under various climate scenarios (baseline, mild drought, severe drought) for the period 2012-2030 was computed by Biogenerator (ACF); livestock population dynamics and feed requirements for different interventions (baseline, animal health improvements, male cattle early offtake) were extracted from MMAGE (CIRAD); feed rations and balances were calculated by GLEAM (FAO) and levels of demand, supply and prices were analysed with IMPACT (IFPRI).

Results show that interventions can significantly increase the output of livestock products (5% to 20% in meat production) if accessibility to feed is improved. This can be achieved through enhancing livestock mobility, developing feed processing and transport and supporting market integration. Livestock systems have the potential to buffer climatic variability through consecutive filters and management decisions: mobility, animal physiology, feeding practices, herd management and eventually milk production and offtake rates. Livestock proves to be a significant asset for adaptation to climate change and interventions should be designed to fully take advantage of this potential.

Parallel session L2.3
Combining mitigation, adaptation and sustainable intensification

Tuesday, 17 March 2015

14:00–18:00

ROOM SULLY 3

KEYNOTE PRESENTATIONS

14:00 *Ex-ante* evaluation of Climate-Smart Agriculture options

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Climate-smart agriculture (CSA) involves sustainably increasing agricultural productivity and incomes, adapting and building resilience to climate change, and, where possible, reducing and/or removing greenhouse gas (GHG) emissions (FAO, 2013).There are many paths to achieve these goals, however, depending on the environmental and social context in which an agricultural system operates. Hence CSA practices may include all aspects of crop, soil, and water management—from tactical considerations involving time of sowing and crop maturity, to nutrient, water, and pest management and conservation tillage options, as well as strategic decisions about crop selection, rotations, and multiple cropping, or investment in irrigation infrastructure. While field studies can evaluate and identify a set of "climate smart" practices that function well at a given location in today's climate, it is not possible to evaluate them in future climates. Crop and cropping system simulation provides a means to perform such ex-ante evaluations assuming. At issue is the source of weather data to use for such assessments. Two potential sources are: (i) a "grafted" weather data set produced by imposing a climate change scenario on top of observed weather data, or (ii) weather data estimated at that location as simulated by a regional or global circulation model sensitive to climate change.

In absence of long-term weather data at many locations, and especially in many developing countries, simulations of climate change impact on crop yields have relied on gridded weather data (GWD) with complete terrestrial coverage derived from global circulation models, interpolation, and satellite remote sensing. Examples of GWD include CRU (New *et al.*, 2002), NCEP (Kanamitsu *et al.*, 2002), and the NASA-POWER database (http://power.larc.nasa.gov). Recent studies, however, have shown that simulated yields using GWD, which provide the basis for climate change scenarios in these previous studies, are in poor agreement with simulated yields with observed data resulting in large error and bias, even in countries with good quality weather data such as the USA or Germany (Van Wart *et al.*, 2013a). Hence estimates of climate change impacts on future crop yields based on these GWD would likely give highly unreliable results.

Given poor performance of the "top-down" approach with GWD, is there value to using a "bottom-up" approach that upscales observed weather data from a network of weather stations located in the major areas of crop production to provide a robust estimate of crop production capacity under climate change at regional to global scales? A bottom-up approach would impose a climate change scenario on long-term daily weather data from existing stations and then upscale through agroecological zones (AEZs) that represent a relatively uniform environment for crop production. Initially only the effect of temperature and atmospheric [CO_2] would be evaluated because model projections of rainfall change vary much more than projections of temperature change (Collins *et al.* 2013; Rocheta *et al.*, 2014). At issue, then, is how to perform the upscaling?

The Global Yield Gap Atlas (GYGA) has developed an upscaling protocol to improve regional to global estimates of yield gaps for the major food crops (www.yieldgap.org). Robust estimates of yield potential, either rainfed (Yw) or irrigated (Yp), are needed to calculate the yield gap, as well as an accurate estimate of current farm yields (van Ittersum *et al.*, 2013). Potential yields are simulated for a set of weather stations selected because they are located in climate zones that contain a large proportion of production area for the crop in question. Detailed data on soil properties and crop management employed by farmers in proximity to each weather station, represented by a 100 km buffer zone, are used as input to the crop simulation models. Simulated yields are then aggregated within spatial units from the AEZ (a combination of soil type and climate zone within the buffer zone around a weather station), to climate zones (Van Wart *et al.*, 2013b), and national spatial scales based on weighting each weather station x AEZ x climate zone combination for production area of the crop in question.

For countries in which good quality soil and long-term weather data are available, evaluation of the GYGA upscaling approach has proven to be robust. For example, a comparison of analogous climate zones in Argentina and Australia found much greater cropping intensity in Argentina than in Australia. Whereas an annual rotation of wheat, sorghum, or chickpea was the dominant system in Australia, a large proportion of Argentine farmers were producing two crops per year for a cropping intensity of 1.0 in Australia and 1.5 in Argentina. Subsequent simulations of a wheat-mung bean double crop in the Australia climate zone found that both income and profit were nearly doubled with the double crop without increasing the risk (Hochman *et al.*, unpublished).

We therefore propose a bottom-up approach for assessing impact of climate change on crop production capacity, and benefits of CSA options, via the following approach, which follows upscaling protocols used in GYGA, which can be applied at a national, regional or global level:

1. Identify the minimum number of weather stations and associated 100-km buffer zones within climate zones to achieve 40-50% coverage of total production area at the spatial scale of interest (*e.g.* regions, countries, continents, or global) with separate impact assessments performed for rainfed and irrigated crop production. Previous work has shown this amount of coverage gives robust estimates of simulated yields (Van Wart *et al.*, 2013c; van Bussel *et al.*, unpublished). This method leads to a tractable number of locations where detailed data are required to support simulation, including data on soil types used for crop production and current crop management practices. A minimum of one weather station should be located in all climate zones containing >5% of crop area at the scale of the study (*i.e.* national, regional, or global). For climate zones with >5% of total crop area in which there are no weather stations with adequate long-term data, the best available "synthetic" weather data can be used, such as those from a GWD source.

2. Obtain required data for simulation of yields, including properties of dominant soil types used for crop production within each weather station buffer zone.

3. Impose a climate change scenario weather database for a target year (*e.g.* 2050) on the daily weather data for each weather station by increasing the daily maximum and minimum temperature by the average increase in temperature and atmospheric [CO2] predicted for that location by a single or ensemble of global climate change models (GCMs). Temperature increases would take into account differences in magnitude of increase in maximum and minimum temperatures, and seasonality.

4. Using a robust crop simulation model that has been well validated across the range of environments represented by the selected weather station buffer zones, simulate Yp or Yw obtained by CSA options under the climate change scenario weather database across the major soil types used for crop production using optimization procedures to identify the crop calendars that optimize yields with acceptable levels of risk (*i.e.* coefficient of variation in yield).

5. Consistent with economic theory and observations, it is assumed that average farm yields can only reach 85%of Yp and 75% of Yw (Cassman *et al.*, 2003; Van Wart *et al.*, 2013c). Hence, crop production potential within each weather station buffer zone under the proposed climate-smart practices is estimated as 85% of Yp and 75% of Yw and current crop area.

6. Upscale estimates of crop production potential under different CSA options by weighting estimates of crop production within each buffer zone by proportion of total crop area within the spatial unit of aggregation (*e.g.* climate zones, nations, continents and globally).

We recognize two weaknesses of the proposed approach. First, it cannot account for effects of climate change on variability in temperature (more or less variability), or changes in rainfall amounts and timing, and solar radiation due to cloud cover. However, ability to predict the magnitude and spatial manifestation of these weather variables in future climates is relatively uncertain with current GCMs. Likewise, the bottom-up approach proposed here allows focus on temperature effects without uncertainty associated with GWDs in producing reliable estimates of Yp and Yw by simulation. A second weakness is difficulty in estimating crop production potential in areas not currently under crop production. This limitation could be overcome by obtaining long-term climate and soil data for current natural ecosystems with potential to produce crops although there is growing consensus to avoid expansion of crop area through conversion of carbon-rich and biodiverse natural ecosysetms due to its large impact on GHG emissions and loss of wildlife habitat. Hence the goal of achieving highest possible yield on minimum possible land area represents a key component of mitigating and adapting to climate change (Lobell *et al.* 2013). Hence, most existing crop area must produce yields as close to the yield potential ceiling as is economically and environmentally acceptable, which typically falls within 75-85% of Yw or Yp.

A final point to make is that access to good quality soil and long-term weather data is essential to support ex-ante assessment of CSA practices in both current and future climates. The good news is that considerable investment is now being given to improving soil data in places like SSA and some other developing and developed countries. In contrast, there is much less investment to ensure good quality weather data in all important crop producing areas worldwide, and there is danger of continued atrophy. And while some suggest that breakthroughs in remote sensing or crowd-sourcing of climate data can overcome disinvestment in weather stations, there is simply no evidence to suggest that such techniques can replace the need for good quality observed data from stations located in major agricultural areas. We conclude that investment in good quality daily weather data with spatial coverage sufficient to provide reliable information about climatic conditions during the growing season for the world's most important crop production regions is perhaps the single highest priority investment the public sector can make to help farmers adapt to climate change, and it will also greatly improve our capacity to assess the impact of climate-smart practices.

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14:30 Will sustainable intensification get us to 2 degrees Celsius?

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Sustainable intensification (SI) of crops and livestock is the current dominant paradigm of agricultural development-- and increasingly of low emissions agriculture. If the aim of SI is to increase food production on a given land area in ways that reduce pressure on the environment and maintain our capacity to produce food in the future (Garnett *et al.* 2013), many of the practices that support SI also reduce greenhouse (GHG) emissions. For example, making more efficient use of land, nitrogen fertilizer, fossil fuels and water in paddy rice contribute to sustainable intensification, but are also practices for significantly reducing emissions. How much can SI contribute to mitigation and would the reductions be sufficient to meet climate change mitigation targets?

To answer this question, we analyse two dimensions of sustainable intensification relative to the 2 degree Celsius goal: emissions from related agricultural practices and emissions reductions from avoided expansion into forest lands and grasslands.

In the 2009 Copenhagen Accord, countries party to the UNFCCC recognized that to prevent dangerous climate change, "the increase in global temperature should be below 2 degrees Celsius" by 2100 relative to pre-industrial conditions.

Using this target and the representative concentration pathway (RCP) 2.6 scenario for 2030, we outline an approach for comparing the emissions likely to result from sustainably intensified agriculture with the reductions estimated necessary in the agricultural sector to meet the 2 degree Celsius target.

The RCP2.6 scenario is the most ambitious of the RCPs produced for the IPCC and represents the goal of achieving 2.6 W/m^2 radiative forcing in 2100, which equates to about 450 ppm of CO_2e and is expected to limit warming to less than a 2-degree Celsius change in 2100 relative to pre-industrial conditions. It includes assumptions about economic activity, energy sources, population growth and other socio-economic factors (Van Vuuren *et al.* 2011).

We examine the mitigation possible from crop and livestock agronomic practices associated with sustainable intensification using data on mitigation potentials from Smith *et al.* (2008) and Smith *et al.* (2013). We do not consider aspects of sustainable intensification associated with pesticides or crop breeding. We also do not consider emissions in the food production cycle from fertilizer production, transport or processing or embodied emissions in these processes.

Our preliminary analysis using this approach suggests that if all practices were adopted at carbon prices of \$20/tCO_2, only 28 to 60% of the mitigation needed in the agricultural sector to reach the 2 degree Celsius target would be achieved. This figure describes only the mitigation in the agricultural sector.

The analysis indicates that using current agronomic practices alone would not be sufficient to close the emissions gap for agriculture in 2030. Rather, new practices with emissions two to three times lower than existing current known practices would be needed. Massive innovation or high levels of adoption by farmers everywhere would be needed. This would be a radical departure from current approaches of promoting known conventional technologies for low emissions agriculture. Other aspects of sustainable intensification, such as breeding more productive crops and livestock that also make more efficient use of inputs and avoided land use change, will most likely be necessary to meet climate targets within the agricultural sector.

To better understand the potential decreases in land area from SI, we review current scenarios for food demand and land conversion of forest and grassland areas and compare these predictions also against the 2-degree goal in the land use change sector. Most scenarios predict further expansion will be needed to meet the globe's 60% predicted increase in food production by 2050 without major shifts in agricultural investment or consumption. Thus, even with the benefits of land sparing, meeting future food demand is likely to create conflict between the objectives of food security and meeting climate targets from avoided deforestation.

This preliminary analysis depends on assumptions related to 2030 emissions projections and the mitigation expected to occur in the agricultural sector under RCP2.6. It also uses a mix of projections from different sources. Developing a coherent set of projections and baselines for both agriculture and land use change will be necessary for a more robust analysis. Further analysis of the sustainability implications is also needed.

Better understanding the potential mitigation from sustainable intensification will help show what other measures may be necessary. Reducing waste and shifting dietary patterns may well be critical to meet targets (Smith and Gregory 2012).

We conclude with observations about the policy measures needed to jointly support sustainable intensification and avoid increased land use change to achieve the 2- degree target.

CONTRIBUTED ORAL PRESENTATIONS

16:30 Climate readiness in smallholder agricultural systems: Lessons learned from REDD+

Zurek Monika, Streck Charlotte, Roe Stephanie, Haupt Franziska with contributions from Wollenberg Lini and de Pinto Alex

Climate Focus, Sarphatikade 13, 1017 WV Amsterdam, the Netherlands

The debate around the role of agriculture in mitigating climate change and sequestering greenhouse gases is politically complex and technically complicated. In many countries, and particularly in developing countries with a large smallholder population, the agricultural sector faces competing priorities, such as national food security goals, poverty alleviation, addressing natural resource degradation and adapting to the already visible effects of climate change. Many of these goals are closer to the immediate, short-term priorities of national decision-makers, relegating climate change mitigation to a secondary priority. It is therefore essential to implement mitigation strategies in concert with strategies that increase the resilience and increase the productivity of agricultural systems.

In the forestry sector, international negotiations on an incentive framework for reduced emissions from deforestation and forest degradation (REDD+) have triggered action at the multilateral, bilateral and national levels to design policies that support activities taken to avoid forest-based emissions and change land-use management. The objective of this study is to evaluate to which extent the REDD+ experience can serve as a model for agriculture, whether a readiness process as in REDD+ would be useful for agriculture, how it could be structured and implemented, and if overlaps and synergies in the REDD+ readiness or other climate readiness processes could be incorporated.

Despite differences in the forestry and the agricultural sectors, experiences from the REDD+ readiness phase can offer useful lessons for an agricultural readiness process. The REDD+ readiness process created an overall coherent structure, framework and process of guiding countries towards developing the technical and institutional ability to integrate mitigation activities into their land-use sectors. In addition to the key lessons, the paper describes the components of a possible agricultural readiness process and lays out the basic steps for its implementation at the country level.

16:45 Assessing low emissions agricultural pathways under alternative climate policy regimes

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With almost one quarter of anthropogenic greenhouse gas (GHG) emissions and high potential for GHG sequestration, the agricultural and land-use sector has to be part of any strategy for climate change mitigation. The contribution of agricultural mitigation depends on socio-economic development, the stringency of the emissions ceiling, and the design of climate policy. The extent of this contribution and its composition, however, is not yet well understood. Applying the IIASA integrated assessment modelling framework with GLOBIOM used for the agricultural sector, we analyze the extent of agricultural mitigation required to stay within emissions levels given by the Representative Concentration Pathway (RCP) 3.7 for three Shared Socio-economic Pathways (SSP) up to 2050. The effects of policy assumptions for exemptions from climate policy for selected developing country groups on mitigation, emission levels, and climate forcing and temperature are assessed. The extent of agricultural mitigation to limit emissions to levels consistent with RCP3.7 is 5.0 $GtCO_2eq/yr$, 8.8 $GtCO_2eq/yr$ and 8.2 $GtCO_2eq/yr$ under SSP1, SSP2, and SSP3, respectively. The bulk of abatement comes from mitigation in land use change (LUC), which contributes about 95% until 2050 under all SSPs. Mitigation in crop and livestock production accounts for 5% of abatement, with the highest potential in livestock production (up to 82%). Forest-rich countries in South America, Sub-Saharan Africa, and South-East Asia with high potential to reduce LUC emissions bear the largest share of mitigation. Policy exemptions for the BRICS, tropical forest basin countries, the LDC or the group of all developing countries lead to shortfalls in mitigation of up to 2.5 $GtCO_2eq/yr$, bringing the world closer to forcing levels as in RCP4.5 and the associated temperature increases. This underlines the need for global collaboration in policies for climate change mitigation in agriculture.

17:00 Climate-smart coffee systems in East Africa

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It is well known now that in East Africa climate change will have a massive impact on the productivity of coffee and on the livelihoods that depend on it. In this study, current and future suitability of coffee were mapped using 19 climatic variables and 21 IPCC models. The maps were validated with field data. Furthermore, long-term historical data was used to confirm the impact of climate change on coffee productivity. Although we know that climate change will have an impact on the productivity of coffee, smallholder coffee systems also face other constraints at various levels that need to be understood in order to develop climate-smart systems. With the proof that climate change will lead to a decrease of coffee productivity and with knowledge of the major constraints in the different coffee-based systems not only at plot level but also at household, community and landscape level, we have developed shaded systems combining cash and food crops that can play a major role in adapting East African coffee smallholder systems into areas where population pressure keeps on increasing. Developing these strategies, we show that only thinking about getting farmers more 'technified' is not the right solution. More cash in the pocket does not necessarily mean more food security and more resilience. Furthermore, strategies currently promoted by the industry often lead to more gender imbalances than before. We show how developing CSA practices need to take constraints and actors at nested scales (*i.e.* from plot to region) into consideration. Doing this in a participatory way is crucial to ensure impact in the long term.

17:15 Prioritizing climate-smart agricultural interventions at multiple spatial and temporal scales

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Climate-smart interventions have varying costs and environmental and economic impacts, and their implementation requires appropriate investment decisions in both on-farm capital of individual farmer and wider community-level agricultural outreach programmes that are relevant in current as well as future scenarios of climate and economic development. Decision support tools are therefore needed that can assist different stakeholders to prioritize and hence take appropriate strategic interventions to transform agriculture to become climate-resilient, adaptive and efficient. This study highlights the development and validation of the Climate Smart Agricultural Prioritization (CSAP) toolkit. This toolkit develops a dynamic, spatially-explicit optimisation model to explore a range of sectorial growth pathways coupled with climate-adaptation strategies. Integrating detailed bottom-up biophysical, climate impact and agricultural-emissions models, this tool is capable of supporting multi-objective analysis of agricultural production in relation to food self-sufficiency, incomes and mitigation targets. CSAP toolkit supports wide range of analyses ranging from food security assessment to preparation of climate smart development plans. The CSAP toolkit is demonstrated on a case-study application for the state of Bihar, situated in the Indo-Gangetic plain of northern India. We develop a range of baseline growth scenarios and assess their vulnerability to climate-change impacts for near-term (2020s), mid-term (2050s) and long-term (2080s) under CMIP5 based new emission scenarios. We then explore the potential strategies for climate change adaptation and the resulting priorities for investment in climate-smart agriculture in the near and long-term (2020 to 2080). The investment required to climate-proof agricultural development is explicitly identified – providing valuable bottom-up evidence to support top-down estimates of the costs of climate change adaptation. Through application of the model to a range of constrained growth pathways we have been able to demonstrate the potential of the model to identify priorities for investment in: (i) Crops best suited to delivering target growth under impacts of climate change on yields; (ii) Technologies to deliver targeted increases in growth based on potential yield increases and efficient use of resources; and (iii) Locations for priority investment given existing surplus productive capacity.

CSAP was developed to bring analytical rigour in planning process and in solving developmental problems – in particular supporting the developing countries in their preparation of National Adaptation Programmes of Action (NAPAs), National Adaptation Plans (NAPs) and Nationally Appropriate Mitigation Actions (NAMAs) under the UNFCCC framework.

Parallel session L2.4
Breeding and protecting crops and livestock

Tuesday, 17 March 2015

14:00–18:00

ROOM RONDELET

KEYNOTE PRESENTATIONS

14:00 Plant breeding for climate-smart agriculture

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Plant breeding is the activity of developing diverse plant varieties that can contribute usefully to cropping and production systems. These breeding efforts are directed at plant improvement. But 'improvement' is a subjective and relative goal and it is useful to regularly break up plant breeding objectives and procedures into clearly defined and manageable units.

Owing to the imperatives of food security, plant breeding must combine the objective of ecological intensification with that of adaptation to overall societal and global changes. It must integrate diverse objectives and selection criteria. It must accommodate demands made by new stakeholders willing to help define objectives and evaluate breeding results.

The so-called "genetic gain" must not only consider the benefits reaped by a farmer using an improved variety at the level of his/her plot, but also its expected economic, social and environmental impacts on a larger scale in the event of a wider dissemination of this variety.

Plant breeding is also a business which must ensure a 'return on investment' and produce goods (new varieties) that ensure a convergence of interests of different economic stakeholders.

Climate change is projected to reduce yield growth rates in much of the world, especially in tropical regions. The Intergovernmental Panel on Climate Change (IPCC) reported that climate change might reduce yields per hectare of wheat, rice, and maize by up to 2 percent per decade starting 2030 compared with projected yields without climate change. Many regions will face increased water stress because of rising competition for water resources and altered precipitation patterns linked to climate change. Furthermore, except in Africa, fertilizer application is already at or above agronomically or environmentally sustainable levels and many regions have maximized their use of irrigation.

Crop breeding can be considered helping address climate change-related stakes by 1) helping enable farmers to avoid crop losses related to climate change to the degree that it results in crop varieties that are more resilient to the effects of climate change and 2) helping reduce greenhouse gas emissions from agriculture by preventing further land conversion to agriculture thanks to increased yields per hectare as well as by reducing the need for fertilizer thanks to increased fertilizer use efficiency.

Global change occurs at such scales and speeds that agricultural systems could respond by replacing species rather than by seeking better adapted varieties of the usual species. Therefore, it is also necessary to foresee the evolution of a 'portfolio' of species used in target regions. The likely increase in diversity and turnover of ecological, agronomic and socio-economic situations for each species raises the question of which varietal deployment strategy to select. Should one select many local genotypes with short lifespans or fewer versatile varieties with longer lifespans?

Biological sciences are going to strengthen the foundation for plant breeding. After diffuse domestication of crops, the integration of science into formerly empirical breeding coincided with the emergence of genetics and heredity. Applied in concert with a spirit of industrialization, it led to the emergence of a whole plant breeding sector of economic activity and enabled the 'Green Revolution'.

During this time, plant breeding activities have been undertaken in an agricultural context of artificialization and standardization of the crop environment. Only a limited number of target environments were considered and plant breeders optimized the use of resources and practices – population size, selective pressure, etc. – in this configuration. This approach was very effective in applying quantitative genetics while according limited importance to the biological fundamentals of variation in traits and adaptation. How to maintain such growth in crop yields in increasingly difficult physical conditions due to a changing climate and increased water scarcity?

The key challenge in biological sciences, and the key opportunity, is of integrating knowledge at different scales in the functional dimension – of molecules, tissues, organs, whole plants and crop stands at different phenological stages, as well as in the recombinational dimension –of nucleotides, genes, genomes arrangements, populations, species complexes.

Functional diversity. Recent technological and methodological developments in the field of genomics now offer the opportunity to understand the patterns of regulation by genes and assessing their relevance to the spatio-temporal variability of constraints for which an improvement is required. Climate change is likely to modify patterns of stresses that affect the plants and lead to revision of plant ideotypes for guiding breeding objectives. In this context the key features are probably: Water use efficiency; Plant phenology; Response to CO_2; Nitrogen use efficiency.

This requires collective organization of phenotyping resources so that they can be accessed most widely and easily.

Re-combinational diversity. There is generally a wealth of germplasm available in collections and on sites in farmers' communities. The biological quest then becomes that of localising favourable genetic factors on the genome, within the distribution of the species and its relatives. There are sampling methods that facilitate this search as long as germplasm is well preserved.*, which are based again on molecular tools that span the diversity along the genome.

The same tools can then be used for steering recombination in progenies or possibly as well in materials derived from genetic engineering. This confers breeders the ability to select on the basis of "genotypic values" estimated early with techniques applied in laboratories. This opens opportunities for actions such as:

- Whole-genome analysis and selection on the basis of carefully studied training populations
- Genotype recombination to maximise genotypic diversity in search for novel assortments
- Genotype designing in order to explore stepwise variation around widely appreciated cultivars.

This requires collective organization of genomic resources so that they can be accessed most widely and easily.

Computational biology. Modern biology is extremely data-intensive. Technologies rapidly gain in throughput, amplifying the dimensions of the data systems, which require validation, organization and integration. Modelling must be applied to a whole range of questions, be they focused on the genome, the populations, the plants as a system, the interactions, etc.

This again requires collective organization of resources, here computational, so that they can be accessed most widely and easily.

In the context of climate-smart agriculture, **plant breeding must also not forget** to address more diverse needs and take into account more complex biological functions which are in interaction with other organisms of the cropping systems. In some cases, these functions can be explained by specialized research and can be translated into absolute selection criteria (*e.g.*, an intrinsic ability to use mineral resources). In a majority of cases, however, new and multifaceted phenotyping methods of unprecedented complexity will have to be implemented, ones that use biological interactions.

Plant breeding must also expand its scope to include a greater number of species in order to encourage a general expansion of the biological bases that agronomists and farmers rely upon. We will have to expand the range of species we work with to include new ones, especially service species and/or those that have not been – or are as yet little – domesticated. Our range of breeding objectives and conditions under which we undertake breeding should also be expanded.

Plant breeders should focus on developing new skills in multigenotypic breeding for using internal complementarities in order to create complex crop stands which are conducive to ecological intensification.

Associations with farmers – in their roles as intermediaries or full partners – must be strengthened and simplified. This will require an analysis of roles of all actors, a translation of methods and a structuring of partnerships in order to optimize the process of innovation as a whole, including the fine-tuning of the innovation to the local context. Dissemination methodologies and approaches will remain important issues and a source of determinant technological options.

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14:30 What impact of climate change on animal health?

Lancelot Renaud, Guis Hélène, Lefrançois Thierry

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Several animal or zoonotic emerging infectious disease (EID) events were recently caused by vector-borne pathogens, *e.g.* bluetongue virus (BTV) transmitted by biting midges which caused huge economic losses in western Europe between 2006 and 2009, and is still around, or tick-borne encephalitis in northern and central Europe, causing several thousands of clinical cases in humans. The effects of climate changes have been put forward to explain these EID events. Because the bio-ecological features of arthropod vectors make them highly sensitive to environmental conditions, vector-borne diseases are ideal candidates to assess the effect of climate changes on EID. The question was extensively studied these past years.

For instance, the effects of climate on BTV's emergence in Europe were evaluated by integrating high-resolution climate observations and model simulations within a climate-driven, mechanistic transmission model of BTV. This model explained, in both space and time, many aspects of BTV's recent emergence and spread, including the 2006 BTV outbreak in northwest Europe which occurred in the year of highest projected risk since at least 1960. Driven by simulated future climate from an ensemble of 11 regional climate models, the model projected an increased future risk of BTV emergence across most of Europe with uncertainty in rate but not in trend.

More generally, results showed that each EID is a special case and involves a complex network of interacting causes. In several cases, socio-economic changes, including the intensification of trade and travels, were found to have a dominant effect over climate changes. This is particularly true for tick-borne encephalitis in northern and central Europe.

Conversely, the indirect effects of climate changes on animal health have been rarely studied so far. For instance, regarding northern and sub-Saharan Africa, climate-change scenarios often point to important consequences on farming systems (*e.g.*, greater importance of small ruminants with respect to cattle) and urbanization. These changes will cause major changes in transboundary livestock trade, thus allowing the introduction of pathogens (and their possible vectors) into previously free areas. This is a further illustration of the need to better control animal diseases in their geographic are of endemicity, and to improve surveillance and preparedness for early warning and reaction in case of high risk of EID.

CONTRIBUTED ORAL PRESENTATIONS

16:30 Reducing nitrogen run-off and emission, and increasing rice productivity in African rice production environment

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Nitrogen (N) deficiency is a common problem of economic importance in rice. Thus, N fertilizers are a major input cost in rice production and its excessive application leads to high environmental pollution. Development of rice varieties with improved nitrogen use efficiency (NUE) is essential for sustainable agriculture. NERICA4 (New Rice for Africa) rice lines over-expressing barley alanine amino transferase (HvAlaAT) under the control of a rice stress-inducible promoter (OsAnt1) were evaluated in the framework of an international humanitarian effort. The result of field evaluations over three growing seasons in three environments (Colombia, Ghana, Uganda) and three nitrogen levels (30, 60 and 90 kg N/ha) revealed that grain yield of OsAnt1:HvAlaAT lines was significantly higher than wild type and null sibling controls under different N application rates. Our field results clearly demonstrated that this gene insertion can significantly increase the dry biomass and grain yield compared to controls under low N supply. Increased yield in high-performing lines correlated to early establishment of vigorous root system, increased tiller, panicle number and grain weight. However, preliminary analysis of metabolic composition of high-performing events did not show significant differences compared to controls. Our results suggest that the HvAlaAT gene has the potential to improve NUE, which will significantly reduce N fertilizer usage, improve productivity, augment farm economics and minimize greenhouse gas emissions from the rice ecosystem, thereby improving food security and simultaneously reducing environmental pollution. Currently, Nerica lines carrying combined gene insertions for NUE and salt- and drought tolerance, potentially harnessing crops for climate change, are being field tested.

16:45 Utilization of ex situ collections and climate analogues for enhancing adaptive capacity to climate change

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Climate smart agriculture hinges on the cultivars with greater adaptability and resilience. This in turn necessitates the use of a wider range of intra-specific diversity conserved in the genebanks. Estimation of adaptive capacity of genebank accessions based on passport data and identification of germplasm accessions with excellent adaptation potential can help develop climate smart crop varieties. Globally, genebanks are working to bring together the inherent diversity of ex situ collections and power of climate analogues for enhancing adaptive capacity of food crops to climate change.

We attempted to employ climate analog tools to identify pre-adapted germplasm (value addition to genebank collections) and vulnerable areas (for collection and conservation) in five selected crops — wheat, pearl millet, chickpea, pigeon pea and sorghum. The methodology comprised geo-referencing and clustering the accessions, climate matching and identifying vulnerable areas, designating pre-adapted material, collecting germplasm from predicted sites, and developing database and climate maps.

Information on 38,126 genebank accessions collected from India belonging to five target crops was mined and the accessions were geo-referenced and mapped based on their collection sites. Locations were clustered (FloraMap) based on the climatic attributes observed over the growing season. Changes in the mean maximum temperatures confined to cropping season for each of the five crop species were employed to map (ArcMap) areas most vulnerable to changing climate. Vulnerable sites thus identified were further supported by climate matching (MaxEnt). Further, 137 genebank accessions originating from sites experiencing top-bracket temperature variables were provisionally designated as pre-adapted for elevated temperature regimes.

Tools to predict and identify of vulnerable sites are becoming sophisticated and realistic. These tools need to be employed for identification of critical sites for collection and recollections of germplasm including landraces and crop wild relatives.

17:00 Adaptation of Mediterranean bovine livestock to climate constraints. Genetic diversity and breeding systems

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According to IPCC, Mediterranean countries will be particularly affected by global warming, with rising temperatures, reduced rainfall during summer months and recurrent heat waves and droughts; this climate is estimated to move inland. In this context, local Mediterranean cattle breeds, genetically selected to adapt to this harsh environment and breed with specific practices are valuable genetic resources.

In order to identify genotypes and breeding practices capable of coping with the environmental challenge induced by climate change, we propose an integrative approach combining genetic analysis of cattle populations, climate conditions and livestock systems. For this purpose, 21 breeds from three southern (Algeria, Egypt and Morocco), two eastern (Cyprus and Greece) and three northern (France, Italy and Spain) Mediterranean countries were genotyped at 41187 SNPs. These data were combined to those available on breeds from neighbouring areas (Massif Central, Alps). Bioclimatic data (annual trends, seasonality, extreme factors) was obtained from WorldClim, a database for ecological modelling. Meanwhile, we have characterized the breeding systems of these local breeds thanks to questionnaires proposed to experts, completed by several extensive case studies.

Model-based clustered methods and Principal Component Analysis were first performed to address the overall structuration of populations. Then a redundancy analysis was performed to describe how geographical and bioclimatic features shape the genetic variation among breeds. Breeds are clearly differentiated according to geography and climate (temperature, rainfall). Finally, genomic regions that contribute the most to the genetic variation associated to climate are identified. The main features of breeding practices in Mediterranean environment are also determined as well as the main animal traits that breeders associate to breeds' adaptation.

This work was supported by the INRA Metaprogram ACCAF (GALIMED project)

17:15 Towards genotypes adapted to climate change via combination of phenotyping and modelling: The projects DROPS and Phenome

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The period of time from now to 2050 is required for designing varieties able to cope with climate changes. Phenotyping is the main limiting step, now that genotyping has become an almost routine activity. A strategy with four pillars is used in the projects UE-DROPS and IA-Phenome-FPPN, involving public and private sectors. (1) Investigating the genetic variability of plant traits as a response to well-defined environmental conditions. Phenotyping platforms, developed in Phenome, allow the identification of genomic regions associated with traits of interest and the estimation of parameters of crop models for 100s genotypes. DROPS has identified QTLs, usable in breeding, for sensitivity of growth to water stress, for root architecture and for water use efficiency. (2) Investigating the performance and yield of hundreds of genotypes under high Co_2, high temperatures or low rainfall in equipped fields, via detailed imaging using sensors carried by ground vectors developed in Phenome. (3) Testing a large number of genotypes in a wide range of conditions. DROPS analyses yield components in a network of 30 field situations over Europe for 250 genotypes. This allows investigating the genetic variability of the sensitivities of genotypes to high temperatures and drought in the field. (4) Modelling, for testing combinations of alleles in a variety of climatic scenarios and management practices. Climatic conditions sensed by plants have been analyzed in 50 European nodes over 50 years, and in predicted European climates for 2050. Clustering individual scenarios reveals that 4 scenarios capture most of the variability of current climates, but also of predicted climates in 2050. Hence, it is possible to analyze today the performances of genotypes in future climates involving drought and high temperature, by using the current climatic variability between sites and years. We are currently simulating the interests of promising combinations of alleles in different European scenarios.

Parallel session L2.5
Overcoming barriers: policies and institutional arrangements to support CSA

Tuesday, 17 March 2015

14:00–18:00

ROOM BARTHEZ

KEYNOTE PRESENTATIONS

14:00 Overcoming barriers: policies and institutional arrangements to support CSA

Lipper Leslie

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Achieving broad scale adoption of improved agricultural practices with potential to increase productivity and agricultural incomes, that are adapted to climate impacts and that result in reduced emissions growth compared to past trends is the key challenge of climate smart agriculture (CSA). This is particularly the case in developing countries and amongst smallholder farmers who generally have low levels of productivity and efficiency, associated with their limited use of improved technologies and practices.

This presentation will provide a discussion of the nature of technology and practice changes needed to achieve CSA objectives and the implications for the types of barriers producers face in adopting them. The analysis takes explicit account of the impact of climate change in reshaping and augmenting the role and importance of institutions and policies to support the rate and level of adoption required to make significant progress on the three CSA objectives. Newly emerging empirical evidence on the impact of climate change effects on agricultural production decisions and current institutional barriers to their adoption will be used to illustrate the importance of improving policies and institutions to reach desired adoption rates. The presentation concludes with a discussion of major research gaps in this topic area and potential ways to address them.

Although CSA practices must be evaluated in light of site-specific conditions, we do have a good sense of some of their key features– and much of this is built upon the experience with sustainable agricultural intensification and sustainable land management. These include practices that increase input use efficiency, such as integrated nutrient management, integrated pest management and improved livestock feeding practices, as well as sustainable land management practices such as agro-forestry, soil and water conservation measures and legume intercropping. The adoption rates of these types of practices have generally been found to be quite low and local institutions play a key role in determining adoption patterns (Thornton & Herrero 2010; McCarthy *et al.* 2011; Arslan *et al.* 2013).

Key features of these practice changes and technologies are their site specificity, information intensive, often involving delayed returns but potentially increased risk in the short run, frequently requiring collective action to implement as well as well-functioning input supply systems. Thus institutions that govern information flows, risk management, financing, input supply and collective action are key to facilitating the broad level of adoption of CSA that is needed to meet urgent challenges.

Farmers' access to information about new practices and technologies, as well as input supply systems, price and market information have all been found to have significant impacts on adoption pattern. Climate change will increase the need for information flows to overcome barriers, since its impacts are heterogeneous over time and space and it increases uncertainty. Analysis of nationally representative farm household data from a range of countries in sub-Saharan Africa indicates the strong and positive impact of extension on adoption of improved practices, as well as rural radio, indicating the importance of information flows and building institutional capacity to extend it for overcoming this key barrier.

Risk has long been identified as a significant barrier to adoption, and climate change augments its effects. However, there are few empirical studies that explicitly evaluate the impact of climate risk on the adoption of agricultural practices with high CSA potential and with the capacity to reduce production risk by enhancing resilience of the production system. Asfaw *et al.* (2014) find a statistically significant and positive impact of rainfall variability on investing in and maintaining both trees and soil and water conservation structures, and with adoption of legume intercropping.

Short run negative returns to CSA practices is another key barrier to adoption. Building ecosystem services such as soil quality, water retention, pest and disease resistance, takes some time to generate productivity and income benefits, while the up-front costs of investment can be substantial. Credit could play an important role in overcoming this barrier but evidence indicates this is generally not happening. In Zambia, only 10% of households had received any agricultural loan in 2008, down from 13% in 2004 (Arslan *et al.* 2014).

The capacity to take collective action is an essential determinant for the adoption of many CSA practices since they often involve generation of public benefits and thus the individual's incentive to generate them is insufficient in the absence of group action. Examples include windbreaks, terracing, other water management structures and grazing management where coordination of group action is needed to generate the benefit. Land and water tenure systems play a key role here.

Poorly functioning input supply systems prevents producers from increasing the efficiency of their input use and moving into new practices. Limited access to seedlings has been found to be a major constraint to agro-forestry adoption in several countries, while timely delivery of fertilizer supply a key determinant of productivity in Zambia.

The final section of the presentation is devoted to a discussion of the implications of these findings for building the policy and institutional environment needed to support extensive, effective and long term adoption of CSA practices and technologies across a wide diversity of production systems, socio-economic conditions and agro-ecologies. The presentation concludes with a discussion of where we are seeing major gaps in our understanding of institutions and adoption patterns, and what kind of research agenda is needed to address it.

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14:30 Policies and institutions conducive for enhancing the transfer to CSA in Africa

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Background

In 2014, declared by the African Union (AU) as the "Year of Agriculture and Food Security in Africa", the AU launched its Science Agenda for transforming African agriculture, an agenda directed by the principles of Climate Smart Agriculture (CSA). The main objectives agreed upon for the Science Agenda are (i) sustainable productivity in major farming systems; (ii) development of food systems and value chains; (iii) agricultural biodiversity and natural resource management, and (iv) mega trends and challenges for agriculture in Africa. In the same year, the publications of the IPCC confirmed its previous climate predictions for the continent, including a rise in temperatures, uncertainty about rainfall expectations, weather extremes (*e.g*. droughts and floods), and the consequences of these climate changes. These consequences include environment-triggered migration and wide-spread poverty, which in turn will hinder people and states from coping effectively with climate change and climate variability (CC & CV). Nevertheless, consensus exists that one of the culprits of CC & CV, agricultural land use, at the same time represents part of the solution when transitioning to CSA in order to reach a food and nutrition secure, poverty-free Africa. Despite the on-going discussion on the sufficiency of present technologies and innovations for implementing CSA, scientists including policy makers agree that current CSA-enhancing policies and institutions are definitely insufficient. Africa needs to further develop its knowledge-generating (research), educative, communication, and financial and investment instruments to unlock the vast agricultural potential of the entire continent. This presentation discusses the various institutions and most challenging policies needed to achieve Africa's unprecedented transformation to CSA. It does not prioritize tomorrow's issues, since this is already handled by many others, but the issues requiring development over the several years to come.

Science and knowledge generation

Because it is unclear to what extent current technologies can increase land productivity under the uncertainties and stresses of future climate change, current decision-making on local, national and regional levels is modest to absent in Africa. Due to this great incertitude, much higher than elsewhere in the world, policy makers need sound science to aid in the evaluation of the relative merits of their available options for a transformation to CSA. Sorely missing are, for instance, (i) continuous data of sufficient quality, and (ii) analysis and synthesis of this data leading to (iii) novel, viable solutions and policy recommendations, as well as (iv) the experts who can fill these gaps. Climate Service Centers (CSC), such as WASCAL in West Africa, and SASSCAL in South Africa, are designed to achieve these above objectives by providing sound, evidence-based information and advice to the public and private sectors. Such centers are established, through the elaboration of an over-arching concept, coordination, cooperation and far-sightedness, to provide policy-relevant information to stakeholders on CC impacts, mitigation measures and adaptation strategies. They act as interfaces between climate-researchers and climate-counselors, and as clearing houses for CC related matters.

Education

The future of Africa and its intended transformation to CSA depend on knowledge and skills, which in turn depend on quality education. Enhancing human and institutional capacities and the frameworks for building those capacities, such as WASCAL promotes, necessarily includes establishing appropriate infrastructure to enable and support technical training and advanced education in natural and social sciences. WASCAL is thus committed to focusing not only on outputs (information and policy advice), but also on the inputs that help to obtain these outputs. The institute is dedicated to embedding a stimulating learning atmosphere in the local science community. Hence, linking higher agricultural education with research, as well as extension with policy, is given utmost priority. Other options include the elaboration of Leadership Programs aimed at building basic science capacity, and the creation and management of highly needed Centers of Excellence. Furthermore, ways must be found to boost the very low science output of the entire African continent. As science and education function as catalytic agents of change by filling knowledge and information gaps, promoting research and education to enhance CSA cannot wait. According to predictions, Africa will gain 10 million youth per annum, about 200 million by 2050. Additionally, women make up more than 60% of Africa's labor force. Both groups, however, have the least access to grants and opportunities. Together with, and to promote an envisaged increase in agricultural productivity, living conditions in rural areas must be made more attractive to youth, whilst women need much better access to education. All other means to ensure that economic growth and development is inclusive, leaving no one behind, must be pursued.

Funding must be mobilized to provide comprehensive, all-encompassing training and education on a score of issues related to the transformation to CSA, from natural resource rights and management, to agro-technology, agro-meteorology, and much more.

Extension

African smallholders produce the bulk of food and other agricultural commodities for the continent, but they are at the same time consistently those with the most hunger. This, despite the annual 35 billion USD of food imported into Africa. The farming community has therefore many reasons to embrace CSA. Existing traditional and indigenous technologies, while effective, cannot cope with predicted rises in temperature, uncertainties in rainfall expectations, and weather extremes such as droughts and floods. Critical support to extension agencies is required to assist farmers in the adoption of technologies and other adaptation measures appropriate to the challenges they now face. For example, given our knowledge of reduced and ceased crop growth during critical stages once temperature thresholds have been bypassed, strategies are needed for buffering against temperature increases, including massive tree plantations. Since Africa remains a continent under pressure, it is not a question of whether or not, but of how and when. As a Chinese proverb states "The best time to plant a tree was 20 years ago. The next best time is now."

Communication

Implementing CSA in collaboration with farmers will be difficult at best, but without farmers' input and acceptance, it will be impossible. Hence communication must be expanded and strengthened to reach farmers and create exchanges of information. This involves the mobilization of all types of media and groups close to the farming population, such as civil society organizations and the private sector, including insurance and telephone companies. Imperative also is the active promotion of public-private–partnerships (PPP) to enable farmers to adopt technologies and innovations that achieve higher, more stable yields, increase their income, and augment regional welfare, all without compromising the environment. An increased trust between farmers and researchers will also encouraging politicians to act on climate smart policy.

Land use

Virtually 800 million ha of land suitable for agriculture (60% of the global reserve) can be found on the African continent. This represents an enormous resource for the future, yet challenging conditions hinder the suitable exploitation of all this wealth. Therefore, science and technology development must be promoted throughout the continent to increase current production and productivity. Both the perspectives and the challenges are vast, given that productivity of Africa's land is, on average, not more than 40% of what it could be, with an average fertilizer use of not more than 10-14 kg ha^2, and less than 4% of land under irrigation. Above all, conditions must be elaborated, in a process driven by science, to increase production and productivity rather than extend land resources.

Financial instruments

The introduction of and transformation to CSA throughout Africa is also about finance; this transformation demands funds and investments. Funds must be freed to support much more agricultural science development and research, as well as the provision of the information and education, as described above. Various countries in Africa enjoy high economic growth rates that had previously been attributed only to the "Asian Tiger Countries". Yet the contribution of African governments to agricultural finance and investment is far below expectations and need. Besides research and education, national administrators need to become highly creative in their pursuit of funds for indispensable improvements in (i) infrastructure, such as irrigation, energy, transport, telecommunication, and post-harvest facilities; (ii) markets needed for inputs and outputs; and (iii) the development of processing capacity, because being the largest producer is not enough, one must also be the largest processor.

Current fiscal management also needs urgently to address and curb the annual outflow of 50 billion USD from the African continent. On the other hand, private sector funds flowing into the African continent already exceeds current bilateral aid by seven times, illustrating the great interest of the private sector in providing financing. National governments are urged to elaborate legislation supporting investments by private smallholders and private enterprises. Whereas initial CSA development may be launched with public funds, enabling conditions must be created to increasingly include and mobilize private sector funds. Means must also be found to increase the contribution of the farmers, who are the largest private sector in Africa.

Conclusion

Under a business-as-usual scenario, Africa will be hit much harder than any other continent by the impact of global warming and consequent CC & CV, not only physically with uncertain temperatures and weather extremes, but also socio-economically. The continent is constantly looking for strategies that will turn the tide. The transformation of Africa's agriculture to Climate Smart Agriculture has been launched on the continent with the realization that governments and other institutions commit themselves to highly creative pursuits of improvements. To mobilize the sleeping giant Africa, the significant achievements of the past need to be complemented and continued with innovative actions. Enabling policies and instruments must enhance knowledge generation, improve education and communication, acquire financing and promote investment. The Climate Service Centers WASCAL and SASSCAL will contribute significantly to the research and education that inform these crucial policies and instruments.

CONTRIBUTED ORAL PRESENTATIONS

16:30 Schools as climate smart agriculture information hubs

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This paper scrutinizes how schools can serve as nuclei of information on climate smart agriculture (CSA), particularly in remote rice farming communities in the Philippines. It is drawn from one year of implementation of the Infomediary Campaign in 81 agricultural high schools. The campaign aims to engage the youth in agriculture, and to create alternative communication pathways in addressing information poverty on rice farming in rural communities. CSA modules were integrated in the curriculum of participating schools. Methods used in this research were survey, focus group discussions, snowballing (to determine the extent of information sharing that transpired) and participant observation. Questions asked ranged from the changes in the knowledge of the students on climate change as well as the extent by which they transferred the information they learned from their classrooms to others, particularly to farmers in their respective communities. There is strong evidence of sharing CSA information by the students to their farmer-parents. The teachers served as significant force multipliers of this initiative, as plenty of cases were documented when they went out of their way to promote CSA information through parents and teachers meetings, sharing of modules to non-Infomediary Campaign participating schools in their community, and engaging local executives. Frequent communication with participating schools and optimization of the participatory approach in all stages of the campaign were seen as its strengths. As it stands, plenty of work needs to be executed to scrutinize the infomediation process, particularly on the roles of champions. Additionally, there is a need to better convey the relevance of this initiative to key policymakers at the national level. Lastly, there is a need to reflect on how CSA modules can be integrated into the curriculum of non-agricultural high schools, but which are in agricultural communities.

16:45 Advancing CSA solutions through global collaboration: the Global Research Alliance on Agricultural Greenhouse Gases

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The Global Research Alliance (GRA) provides a framework for cooperation and investment in activities that support the agricultural sector in meeting the growing demand for food while reducing greenhouse gas emissions intensity. Its work is focused on improving efficiency, productivity, resilience, and adaptive capacity across the agricultural sector. Established in 2009, the GRA has 44 member countries along with partners such as the World Farmers' Organisation, the Food and Agriculture Organisation and the World Bank.

The GRA organises its work through three research groups: Croplands, Livestock; and Paddy Rice and two cross-cutting groups that work on issues that are common across the three research groups, Soil Carbon and Nitrogen Cycling; and Inventories and Monitoring. The GRA seeks to make faster progress towards emissions reductions by supporting capacity-building and collaborative research and extension projects among its members and partners. Flagship activities include:

- An international comparison of soil carbon and nitrogen models benchmarked with high-quality data from international measurement sites. Joint protocols are being developed to test mitigation and adaptation activities across a range of management practices, soils and climates.
- The development of the crop management database MAGGnet (Managing Agricultural Greenhouse Gas Network) which will inform how agricultural management practices influence greenhouse gas emissions and soil carbon sequestration based on experiments from around the world; currently over 200 studies have been assembled in the MAGGnet database.
- The Animal Selection, Genetics and Genomics Network (ASGGN) provides an open communication link where scientists from around the world can share information and data. The network is a forum to debate and reach agreement on a variety of topics, including common protocols for measuring methane emissions and how DNA and other samples are collected and stored.

Although membership of the GRA is a country decision, individual researchers and organisations from non-GRA countries are encouraged to get involved in GRA Research Group activities.

17:00 Using whole-farm models for policy analysis of climate smart agriculture

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An essential feature of CSA is the reliance on a solid evidence base. This involves combining climatic, environmental, agricultural, demographic, institutional and economic data, while accounting for spatial heterogeneity. Econometric analysis of the evidence base provides useful insights into policies to enhance development and adoption of desirable practices at the local level. Econometric model parameters provide estimates of the marginal response of CSA outcomes to alternative policies, but this can only be done for policies that are included in the dataset and for which enough variation has occurred to provide reliable regression coefficients. The usefulness of the econometric approach can be enhanced through mathematical programming models representing farm households. These farm models explicitly consider technical relationships between inputs and outputs as well as taking into account different constraints faced by various types of households. The range of policies and technologies that can be explored is expanded by allowing the analyst to predict how farm households would react to changes in yields, prices and in the constraints they face, all of which can be influenced through different policy packages. A critical question is how to calibrate the farm-level models to be consistent with the observed behaviour of different types of farmers in particular locations with varying agroecologies. In this paper we use data from Zambia and Malawi to illustrate the development and calibration of these models and their application in policy analysis to enhance CSA outcomes. The datasets we use have broad geographical coverage and contain climatic, environmental, institutional and household data. The focus of the research is on smallholders and the constraints they face in terms of land, labor, capital, access to markets and other factors. The methodology is based on using econometric analyses to provide parameter values for constrained optimization models of farms, which are then used in policy analysis. Examples are presented for policies involving extension, credit, R&D and subsidies.

17:15 Climate shocks and risk attitudes among female and male maize farmers in Kenya

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Climate-smart agricultural practices can mitigate the negative effects of climate change on food security and poverty reduction for rural smallholders in Africa, where crops are largely rainfed. However, attitudes toward risk can affect farmers' adoption of these practices. Unfortunately, little is known about farmers' attitudes towards risk, and how they can be measured. Individual risk attitudes of male and female Kenyan farmers were elicited during a survey of 1344 maize-growing households representative of the major production zones. First, farmers gave self-assessment on a 5-point Likert scale. Next, an experiment to determine risk preference was conducted based on the choice among five lotteries with increasing expected payoffs and standard deviations, followed by an experiment to determine relative risk aversion based on the maximum willingness to pay for a lottery. Spearman's rank correlations indicated that the risk measurements were significantly but weakly related. Although farmers often assess themselves as risk loving, experimental results classify them as risk neutral or averse. Ordinal mixed regressions indicated that women are more risk averse than men, but differences among households were greater than differences between genders. Farmers in moist transitional, dry transitional, and dry mid-altitude zones were more risk averse than those in other agro-ecologies. Climate and market shocks experienced in recent years affected farmers' risk attitudes. Livestock diseases and deaths were associated with self-assessed risk aversion, unusual temperatures with risk preference, and flooding and crop diseases with relative risk aversion. Self-assessment often does not match behavior, indicating the importance of experimental methods. Policy support to reduce vulnerability to shocks can reduce risk aversion and increase uptake of climate-smart technologies. Technology development and targeting need to be gender-sensitive given the higher risk aversion among female farmers and consider the specific locations as farmers in some areas are more risk averse than in others.

POSTER SESSION 2

Tuesday, 17 March 2015

15:00 – 16:30

EXHIBITION HALL, LEVEL 0

L2.1 Developing and evaluating climate smart practices

1. Climate Smart Management Options for Improving the Soil Fertility and Farm Productivity in the Middle Hills of Nepal

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Increasing food demand and climate change pose a major challenge to the sustainability of food production systems and safeguarding environmental health. Nepal's economy is primarily reliant on agriculture which is highly sensitive to climate variability. Key concerns in the middle hills of Nepal include declining soil fertility and soil degradation, changing temperature and precipitation patterns, and pest and disease outbreaks, all of which are affecting productivity, prices, incomes, and ultimately livelihoods. This paper describes some simple, farmer-friendly climate smart management options, and analyses their importance, effectiveness and impacts on improving soil fertility and farm productivity. Simple and widely-adopted sustainable soil management and agronomic practices, which are based on efficient use of local resources, include improvement in preparation and management of farmyard manure (FYM) and compost, systematic collection of cattle urine and its use as a base for botanical pesticide and liquid fertilizer, integrating legumes and fodder crops into cropping systems, small-scale collection of rain and run-off water, and improved water use efficiency. These practices have resulted in a statistically significant increase in soil organic matter levels, and have improved soil fertility and structure, workability, and moisture characteristics. Soil organic matter reached a mean of 3.77% from 3.32% after adoption of sustainable soil management practices over the period of 1-3 years in 337 farm sites. The nitrogen content of topsoil significantly increased overall (0.17% to 0.2%) and in 3 of 5 time series. Similarly, nitrogen content of improved FYM significantly increased in 3 of 5 series and overall on 350 farmer’s fields over a period of 1 to 3 years. 18.6 kg additional N was annually gained from mature cattle with improved farmyard manure management techniques and systematic collection of urine. Additional benefits include enhanced soil carbon storage, and improved crop resilience to changes in weather patterns. Adoption of these practices has contributed to increased productivity, enhanced income, improved food security, and a beneficial impact on the workload of women.

2. Linking an ecological based system and social resilience to build Climate Smart village model in Niger

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[1]*Institut National de Recherche Agronomique du Niger, BP429, Niamey, Niger*

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Smallholder farmers in Kampa zarma climate-smart village coped with unreliable rainfall and drought. These events are associated with land degradation, severe socio-economic impacts that include lack of food, water and for many basic livelihoods. The objective is to increase agricultural productivity and strengthen ecologically based system and social resilience to climate change and reduce greenhouse gas emissions. To address this crisis, households were classified in different categories of vulnerability and options such as improved water harvesting techniques (*e.g.*: Zaï pit and half-moon techniques) on which tolerant cereal-legume, Farmer Managed Natural Regeneration, Field Diversity crop cereal-legume and leafy vegetable are carried out under Farmer Field School. Qualitative and quantitative data were collected to assess performance of different crop varieties, climate resilience, vulnerability reduction and carbon sequestration. Results showed that for 7 varieties of sorghum, the highest average yield (752.50kg / ha) was recorded with Hamo Kirey of Damana. 3 ecotypes and improved variety of okra (RCA), only the latter has performed well with a production of about 12 tons per hectare. Yields were 625.33 kg / ha for zaï with organic matter. 50 farmers were trained on the technical, practical and management of Farmer Managed Natural Regeneration. Half-moons allow rapid restoration of degraded soils, Farmer Managed Natural Regeneration significantly influences the structure of the soil, grain yield and carbon sequestration. Simultaneous achievement in improvement of crop production, quality nutrition, community adaptation to climate change and reduction of greenhouse gas emissions are really striking. It was found that zaï and half-moon techniques combined with the application of organic manure and Di-ammonium phosphate mineral fertilizers are sustainable land management practices that have increased agricultural productivity, vegetative cover and carbon sequestration. They also reduce flood and water erosion. These techniques can be taken for climate-smart since in various ways, they contribute to the Climate Smart Agriculture criteria.

3. Agriculture, climatic risks and food security in disaster-prone coastal landscape of Bangladesh

Ronju Ahammad

Charles Darwin University, Australia

There is growing emphasis on understanding climate change impacts on agriculture and food security in developing and least developed countries. Over the last decades, Bangladesh has recognised climatic variability as one of the key threats to rural food production and overall country's food security. In particular, the agriculture sector of coastal areas is largely susceptible to a range of climatic effects, and it is often difficult to secure food production throughout a year. Seasonal weather variation increases different levels of threats to farming systems in terms of erratic tidal surges, prolonged salinity and lack of irrigation. The study presents the threats and opportunities of coastal agriculture sectors in Bangladesh to understand the patterns of vulnerability in farming systems and capacity to adapt. In-depth interviews of households have been conducted in 4 coastal villages of Barguna District in Southern region to collect information how they face climatic and non-climatic shocks on land use systems and adapt. Focus group discussions provide the information on historical trends of climatic shocks on agriculture systems and constraints in improving local food productions. Based on the information, the study finds that the crop production strategies are inadequate to deal with seasonal weather shocks and emerging threats of pest attack. Diversification of land uses and cropping practices can be effective to improve food production apart from high yielding farming system. However, there are largely needed extension supports of weather forecasting, availability and accessibility to farming inputs, and integration of climatic shocks with existing protective infrastructures. The home garden approach that combines agriculture and tree cropping still dominates food production. In order to enhance the potential roles of the practice, it will depend on improved crop and tree varieties and capacity building of farmers in relation to climatic shocks.

4. Assessing economic benefits of the use of climate seasonal forecasts within cowpea and sesame sectors in Burkina Faso

Ouédraogo Mathieu[1], Barry Silamana[2], Kagambega Levy[2], Somé Léopold[2], Zougmoré Robert[1]

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Climate variability has a large impact on agricultural production due to the fact that agriculture is deeply interconnected with weather and climate. In Sahelian zone, farmers are well aware of climate variability. The ability to understand, monitor and predict the climatic variability provides an opportunity for farmers to put historical experiences into perspective and to evaluate alternative management strategies for making improved decisions to take advantage of good years and minimize the losses during the poor years. The communication of the seasonal forecast, including seasonal duration, final and start rain date, could contribute to support decision-making for climate risk management. This paper used an ex-post assessment method to evaluate the added-value and the cost-benefits of using seasonal forecasts within cowpea and sesame production sector in Burkina Faso. To do this, two groups of farmers were considered for the study. They include experimental farmers who are linked to weather information and agro-advisories through workshops, radio shows, and extension agents and controlled farmers who are not aware to climate information through the channels cited above. We also used the contingent valuation method to determine the willingness to pay for seasonal forecast and its determinants. The results showed that farmers using climate information changed their farm practices in accordance with the information they have received. This affected most of the factors influencing farm income, including quantity of inputs (seed, fertilisers, pesticides) and labor used, contributing to make them more productive, efficient and resilient to climate variability than the non-users of seasonal forecasts. Most of famers accept to pay for the seasonal forecasts. This study suggests that it's very important to undertake more actions to scaling up the use of seasonal forecast at country level as the proof of its capacity to build resilience to climate variability is made.

5. Measurement of climate change and its effect: comparison between an objective method and population perceptions

Azeufouet Alain Simplice[1], Fofiri Nzossie Eric Joël[2], Bring Christophe[2]

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[2]*Département de géographie, Université de Ngaoundéré BP 454, Cameroon*

The objective of this study is to contribute to the research and decision making in the context of the fight against climate change. This work does not extend the appropriate solutions to eradicate the phenomenon, but presents adaptations of populations for research participatory solutions. Meteorological parameters such as rainfall, temperature and humidity, observed in the last 30 years in the municipalities of northern Cameroon and the collection of data by Community expert panel allowed this research, which compares two methods.
The first is to model the monthly rainfall and annual temperature to detect the changes which occurred. The study of the temperature shows the increasing trend each year while the rainfall shows a type of seasonal ARMA (12, 12). This observation can detect the dispersion, differences and irregularities between climate trends around year 2000. The second method characterizes the population's perceptions about climate change. At the end we test the adequacy of observations by objective measures and those by population's perceptions and a critical analysis of the monitoring of information systems on climate change in developing countries to suggest ways of improvement. A test for determining the new weather patterns trend is made to serve as a working basis for policy makers and farmers whose business is most vulnerable to the event.

6. A set of indicators to evaluate policies for climate smart agriculture

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A comprehensive set of tools and indicators is needed in order to evaluate the effectiveness of climate-smart policies and to determine possible alternatives in their implementation.
These tools and indicators should be based on comparable data, integrated within a conceptual framework, that is compatible with monitoring of CSA for a given farm, region or country.
The ultimate goal of these activities is to identify the relevant, succinct and measurable statistics that will provide the basis to further develop CSA policies and progress.
This paper is aimed at proposing a first set of indicators based on existing statistics, that:
- provide a balanced coverage of the different dimensions of CaìSA, including food security, climate change, water management, soil management, energy and conservation agriculture;
- are measurable and comparable across countries and different local situations;
- reflect key issues of common relevance to CSA in various countries;
- are based on existing data sources.

These indicators include:
- agricultural production
- total factor productivity
- growth of crop production
- growth of livestock production
- growth rate in yields
- growth rate in agricultural labour productivity
- growth rate in agricultural capital productivity
- agricultural GDP per unit of agricultural GHG emissions
- share of agriculture in total GHG emissions
- irrigation water per irrigated area
- agricultural GDP per unit of energy use
- renewable energy produced by agriculture
- nutrient balances in agriculture (N and P) per agricultural output and area
- share of farmers with agricultural training
- trends of expenditure on agricultural training and education
- trends in government R&D expenditure on agriculture.

The paper examines the most relevant aspects of each indicator, and discuss their relevance and importance to policies for climate smart agriculture.

7. Developing and evaluating CSA practices at country level: lessons learned from Malawi

Phiri George[1], Lipper Leslie[2], Asfaw Solomon[3], Cattaneo Andrea[4], Cavatassi Romina[5], Paolantino Adriana[3], McCarthy Nancy[6], Spairani Alessandro[7], Branca Giacomo[8], Grewer Uwe[9], Mann Wendy[10]

[1]*CSA Technical Coordinator, FAO, Malawi*

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[4]*CSA Project Leader, FAO Rome, Italy*

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[10]*Senior Policy Consultant, FAO Rome, Italy*

Since CSA is a relatively new approach, there is relatively little experience with operationalizing the concept at country level. This presentation will provide insights and experience from one of the first CSA projects implemented at national level through a partnership between FAO and the governments of Zambia, Malawi and Vietnam. The presentation will take a broad view in defining CSA practices, including policy coordination and capacity building, as well as farmers' practices in the field. The first part of the presentation will summarize the steps taken to evaluate CSA practices at farm, institutional and policy level in the context of Malawi. The presentation will describe the evaluation process to identify key partner agencies and policy processes to support effective CSA development, as well as the development of an evidence base to evaluate the effects of climate change on smallholder agriculture and implications for development and investment strategies. The need to evaluate activities within country specific constraints, opportunities and priorities is emphasized and illustrated with examples. The method and results of analyses to identify climate impacts on agricultural systems at a sub-national level, and the evaluation of a range of practices for their potential to contribute to food security, adaptation and mitigation under the specific climate impacts realized will be a major focus. Results from Malawi indicate that there is considerable variation in climate impacts within the country on both the types of practices most suited to supporting food security, and emphasis on risk management is essential to achieve broad adoption rates.

The second part of the presentation will focus on lessons learned from the CSA pilot activity in Malawi focusing on means of streamlining the evaluation of CSA approaches, as well as gaps that CSA science could help address. A similar presentation from the Zambia country experience is also being submitted to the same session with the intention of providing comparisons between the two country's experiences in approaches to evaluating CSA practices.

8. Developing and evaluating CSA practices at country level: lessons learned from the Zambian experience

Kokwe Misael[1], Lipper Leslie[2], Arslan Aslihan[3], Cattaneo Andrea[4], McCarthy Nancy[5], Spairani Alessandro[6], Branca Giacomo[7], Grewer Uwe[8], Mann Wendy[9]

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Since CSA is a relatively new approach, there is relatively little experience with operationalizing the concept at country level. This presentation will provide insights and experience from one of the first CSA projects implemented at national level through a partnership between FAO and the governments of Zambia, Malawi and Vietnam. The presentation will take a broad view in defining CSA practices, including policy coordination and capacity building, as well as farmers' practices in the field. The first part of the presentation will summarize the steps taken to evaluate CSA practices at farm, institutional and policy level in the context of Zambia. The presentation will describe the evaluation process to identify key partner agencies and policy processes to support effective CSA development, as well as the development of an evidence base to evaluate the effects of climate change on smallholder agriculture and implications for development and investment strategies. The need to evaluate activities within country specific constraints, opportunities and priorities is emphasized and illustrated with examples. The method and results of analyses to identify climate impacts on agricultural systems at a sub-national level, and the evaluation of a range of practices for their potential to contribute to food security, adaptation and mitigation under the specific climate impacts realized will be a major focus. Results from Zambia indicate that there is considerable variation in climate impacts within the country on both the types of practices most suited to supporting food security, as well as the institutional support needed to achieve broad and permanent adoption. The method used for evaluating gaps in coordination between agricultural and climate policies, as well as for identifying CSA investment options aligned with national agricultural priorities will also be covered.

The second part of the presentation will focus on lessons learned from the CSA pilot activity in Zambia, focusing on means of streamlining the evaluation of CSA approaches, as well as gaps that CSA science could help address. A similar presentation from the Malawi country experience is also being submitted to the same session with the intention of providing comparisons between the two country's experiences in approaches to evaluating CSA practices.

9. Millet and sorghum leaf pruning and transplantation as adaptation techniques to rainfall variability in the Sahel

Alhassane A., Traore S.B., Sarr B., Lawali M. N., Seybou O. A. B, Chaibou B.

Centre Régional AGRHYMET, PO Box 11011, Niamey, Niger

In the West African Sahel, agriculture is mainly rain-fed, and therefore dependent on the poor distribution of rainfall. Thus, very frequent dry episodes during the critical crop installation and anthesis stages have an important impact on agricultural production and therefore on the food security of the people of the area. To reduce the negative effects of drought and improve the productivity of the major staple crops in the Sahel (pearl millet and sorghum), we have undertaken since 2012 to try to adapt new farming techniques and optimize the use of rainwater. These tests consisted in observing the effects of leaf pruning and of transplantation of young plants on the water consumption and growth of three millet (HKP, SOUNA3, and SOMNO) and two sorghum (Mota-Maradi and IRAT204) varieties commonly used in Niger. The tests were conducted in the experimental plots of the AGRHYMET Regional Centre in Niamey, Niger (13 ° N, 2 ° E) in the framework of the FACE (Faire face aux Changements Ensemble) project funded by IDRC Canada. Measurements and observations made in the trials included phenology, the accumulation of dry biomass, changes in soil moisture and yield components at harvest. The results show that leaf pruning and transplanting seedlings (grown in a nursery) were beneficial for saving soil water, increasing the number of productive tillers and grain yields. Both practices can therefore be considered as coping strategies to climate variability and change for millet and sorghum growers in the Sahel.

10. CSA menus of practices in the MICCA pilots

Rioux Janie, Rosenstock Todd, Kirui Josephine, Mpanda Mathew, Massoro Erasto, Karttunen Kaisa

Food and Agriculture Organization of the UN, Viale delle Terme di Caracalla, Rome 0015, Italy

Demonstrating the benefits of climate-smart agricultural (CSA) is essential to promote CSA as a priority in agricultural development. The pilots of Mitigation of climate Change in Agriculture programme of FAO in Kenya and Tanzania have been integrated to ongoing development programmes to show how smallholder farmers can contribute to climate change mitigation while improving their livelihood and productivity. The approach was to develop menus of climate-smart agricultural practices based on participatory assessments, to implement the selected practices through different extension approaches, and to evaluate their effects on yield and potential to reduce greenhouse gas (GHG) emissions at farm and landscape levels. The study demonstrated that in cereal-based cropping systems in Tanzania, leguminous trees and mineral nitrogen fertilizer can sustainably intensify production by increasing productivity under conservation agriculture without significantly increasing GHG emissions. In integrated crop-livestock systems analyses in Kenya, the results suggest that smallholder dairy production can be relatively climate-friendly when combined with agroforestry and pasture management. The adoption of the practices was further analyzed to better understand the incentives and barriers, and the multiple benefits as perceived by farmers to inform on CSA implementation and up-scaling (results coming).

11. Sustainability of broiler production in the context of climate change – Evaluation of new incubation strategies

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World poultry production continuously increases to respond to the growing demand for animal protein sources. Selection for fast-growing broilers in temperate climate has resulted in high performances regarding growth and feed efficiency but also to a high sensitivity to their climatic environment. Thus, the higher frequency of extreme temperatures events predicted to occur with climate change might affect negatively broiler performances. Furthermore, the energy cost for heating poultry houses at batch start or cooling them later during heat waves is a major environmental concern. In this context, it becomes necessary to develop and evaluate new strategies and techniques to improve broiler robustness and adaptability without altering flock performances. Thermal manipulations during specific phases of embryonic development to acclimate embryos to cooler or warmer temperatures may be efficient ways to achieve this aim. This strategy could improve the thermotolerance of broilers later in their life when they experience cold or heat stress. Our hypothesis is that cold acclimation of embryos could increase chick robustness and hence decrease the energy use for heating at batch start, while heat acclimation could limit the mortality during heat waves. Consequently, production costs and greenhouse gas emissions from broiler production could be reduced and animal welfare improved. In that context, a large panel of indicators was chosen with researchers and poultry professionals to evaluate the sustainability of this technique according to its economic, social and environmental dimensions. Results should allow the evaluation of this strategy at a farm scale as a tool to limit the negative impacts of different climatic environments on broiler performances. This approach combining experimental data and multicriteria analysis will be evaluated both in temperate (France) and tropical (Togo) countries.

Funding: N.D. is funded by PPAAO-Togo and ITRA for realizing her PhD and studies are funded by INRA (PHASE) and CERSA (Togo).

12. An analytical framework for Climate-Smart Agriculture at the community level

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This paper introduces a participatory analytical framework, the objective of which is to analyse the interactions between adaptation, mitigation and food production at the community level. Making agriculture climate-smart is being embraced by global policy makers as a way to transform agricultural landscapes. Likewise, for smallholder farming systems, climate-smart agriculture (CSA) means realising sustainable development goals at the local level while boosting agricultural productivity and resilience. As adaptation is place-specific and mitigation options for smallholder farming systems can be maximised at farm level, a framework to analyse interactions and evaluate the effectiveness of CSA is useful. A survey of thirty practitioners and policy makers was used to identify key processes and indicators linking adaptation and mitigation with good CSA practices across three broad categories: governance; agriculture and food security resilience; and synergistic relationships between adaptation and mitigation. The governance and resilience categories are useful for understanding the links between institutional approaches to risk management relevant to agriculture, while synergistic processes help relate adaptation actions with mitigation strategies. In exploring the relationship between adaptation measures and their potential for greenhouse gas emission reductions within smallholder farms, four lessons emerge. The first is the need to address immediate risks due to climate variability and subsequent effects on food security and livelihoods. Second, capacity to manage future climate risks and adaptation measures needs to be developed. Third, there is a need to exploit the potential for emissions mitigation and carbon sequestration. Finally, co-benefits are required to help avoid trade-offs between adaptation and likely mitigation outcomes. The framework links practice to theory, compares local solutions, and develops causal relationships between climate change and agriculture. The paper concludes by outlining the methodologies to apply the framework and monitor the success of CSA, which will assist researchers and practitioners effectively implement community-based CSA initiatives.

13. Are cropping practices developed by Sub-Saharan farmers climate-smart? Case study of millet cropping system in Senegal

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Many traditional farming practices can be described as belonging to the climate smart agriculture approach. In this study, we focused on millet cropping systems developed in the Peanut Basin in Senegal. Millet is traditionally cultivated in rotation or in intercropping with legumes as peanut or cowpea. In these systems, chemical fertilizers are rarely used and we hypothesized that nitrogen fixing legumes may enhance the nitrogen availability for the cereal. Our research objective was to evaluate "*in situ*", the effects of the legume intercrop on the agronomic performances of the cereal crop. This question was approached using different data sources: 1) Farmers' interviews on their perception of these effects, 2) Direct measurements on the millet nitrogen nutrition and yield elaboration in selected farmers' fields with and without the legume intercrop, 3) Direct measurements of nodules number, ^{15}N natural abundance of the legumes in a network of farmers' fields. The results brought us to discuss the potential adaptation of the intercropping systems in a future drier climate.

14. Namibia specific climate smart agricultural land use practices: a budding vehicle for improving ecosystem services

Kuhn Nikolaus J., Naanda Martha Talamondjila, Bloemertz Lena

Physical Geography and Environmental Change, Department of Environmental Sciences, University of Basel (UNIBAS), Klingelbergstrasse 27, 4056 Basel, Switzerland

Land Use Practices (LUPs) and Interventions that reduce land degradation offer multiple benefits for subsistence of small scale farmers in northern Namibia's landscapes. These benefits are: increasing harvests and outputs, improving soil health and condition and soil organic carbon (SOC), and increasing woody biomass in the immediate farming (for households) areas as well as at the landscape level. While the latter will be a local source for a major global service (mitigating climate change), its potential is not captured. Namibia's agropastoral farmers mix crop and livestock production on degraded semi-arid land. Mostly, their agricultural harvests and outputs are low, not meeting their needs. In the agricultural forest and other land use sector, arid countries like Namibia have potential to sequester carbon, primarily in three ways, (1) keeping existing dry forest intact or (2) reforestation/afforestation of cleared lands or (3) shifting land use practices towards climate smart agriculture (CSA). The latter, however, will not be substantial for Namibia due to the poor soil quality and the fact that soil organic carbon is generally low on sandy soils, which are mostly found in Namibia. The second one is pivotal given the extent of land degradation from the pressures to meet agricultural food production needs through land expansions. As such, this study presents CSA land use practices and interventions, adopted by small scale farmers, in northern Namibia, providing livelihoods, climate and biodiversity co-benefits. It demonstrates an increasingly important role that farmers can concurrently play to provide and secure global climate services (while pursuing means of livelihood and food production) in eco-agricultural landscapes.

Funding support for this work was provided by the Syngenta Foundation for Sustainable Agriculture.

15. A two-dimension evaluation of CSA practices. Evaluating practices by indicators and reduce non-observable variable bias

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Although there are several agricultural practices that could be contemplated as being in accordance with CSA pillars, not all can offer the same results in a given context and any investment should try to be as efficient as it can. Prioritization strategies or criteria should be implemented or defined so the best practices (in terms in results) may be proposed and executed. Because a great number of practices may be available the strategy should handle several practices in the beginning and reduce the options to just a bunch of them. That is why a two-stage approach is proposed as a part of prioritization methodology. An Economic Cost Benefit Analysis, which is a methodology that has been frequently used for assessing and evaluating investment projects and policies, is the final stage. Although it gives a good possibility to do a better evaluation of projects when their cost and benefits are not purely financial it is not ideal when there are too many options to be evaluated. The first stage works as a filter. It can handle many options by using simple indicators. This strategy generally overestimates those topics that are easy to capture in an indicator, which can be particularly difficult for the CSA practice selection strategies. That is why a multiple dimension structure is suggested for selecting indicators and defining weights for score per practice calculation. Each of the CSA pillars are analyzed in a wider perspective so as to reduce its dependence on the indicators. Adaptation, mitigation and food security is assessed on an economic, social and environmental dimension. Also data quality criteria are proposed for each indicator so it could complement the first stage analysis. A discussion is proposed for future methodologies.

This research was principally funded by CCAFS.

16. Balancing complexity and usability when modelling farm scale production and greenhouse gas emissions

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The AnimalChange project needed a model to firstly assess the production of livestock farms from a global range of geographic locations, and the associated direct and indirect greenhouse gas (GHG) emissions, and secondly assess the efficacy of measures to mitigate these emissions. The model therefore needed to be highly adaptable and readily parameterised, yet to be sufficiently complex that it could realistically reflect the effect of mitigation measures on production and emissions. The model constructed (FarmAC) is a hybrid that contains some elements that draw on the static modelling tradition from the emission inventory community and other elements that draw on the dynamic modelling tradition of the process-oriented scientific community.

The simulation of carbon (C) and nitrogen (N) storage in the soil proved the most problematic, since it was necessary to model this dynamically. This was a) because C sequestration is an important element in the GHG budget of farming systems and such sequestration per definition prohibits a steady-state assumption regarding the soil storage, b) the sustainability of low-input farming systems is particularly dependent on the soil dynamics and c) some mitigation measures (*e.g.* cover cropping) require the simulation of the transfer of N between crops.

The presentation will focus on the challenges encountered when combining static and dynamic approaches within a single model. For the modelling, these included reconciling a static model of grazing ruminant livestock production with a dynamic model of herbage production and bringing the C pools within the soil model into an appropriate state prior to simulating measures. For the users, quantifying the large number of parameters was daunting. The presentation will conclude with a reflection on the advantages and disadvantages of the static and dynamic approaches to farm scale modelling of GHG emissions.

This work was supported by the European Project AnimalChange (no 266018).

17. An impact assessment of distinct agricultural climate protection measures for the implementation on 10 000 Swiss farms

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The reduction of greenhouse gas emissions (GHGE) has become a critical task in agriculture practice and numerous recommendations on climate protection measures (CPM) in agriculture exist. For that purpose, knowing the relative GHGE-reduction potential of a measure is essential to evaluate the impact and efficiency of a CPM and thus its value for realization. However, sophisticated quantifications and comprehensive impact assessments for agricultural CPM, in terms of looking at other environmental impacts, are still sparse. Therefore, we evaluated several CPMs applicable to Central European agriculture on their potential to reduce GHGE as well as on potentially co-existing environmental trade-offs. The aim of this study was to a) calculate the potential amount of GHGE reduced by a CPM, b) identify potentially coexisting tradeoffs, c) evaluate the value and efficiency (costs) for realization of a CPM and d) identify an appropriate method (functional unit) to rank the measures. All CPMs were analysed by means of the Swiss Agricultural Life Cycle Assessment tool (SALCA). For the analysis, 20 measures were selected that had been suggested to be effective and applicable on different Swiss farm types. The SALCA calculations were based on four modeled farms, which represented the statistical average of a certain Swiss farm type (dairy, arable, pig farming and beef production). First results are very surprising as measures aiming at the use of renewable energy seemed most effective to reduce GHGE, while other CPMs within arable farming could even show an increase in GHGE. Overall, as the reduction potential of a single CPM was relatively low, it became evident that only a bundle of measures could lead to a significant reduction of GHGE. Finally, the results of this study, which will be completed in spring 2015, will provide the basis for the implementation of an agricultural climate protection program involving around 10 000 Swiss farms.

18. How biodiversity-agriculture integration meets environmental expectations in a changing climate: a gender perspective

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Integrating agricultural activities with conservation is known to maximise biodiversity and promote sustainable management of landscapes. The current work investigates the relevance of biodiversity-agriculture integration in addressing socio-environmental concerns and in achieving community goals in a changing climate. The study focuses on smallholder communities in a Transfrontier Conservation Area in Southern Africa. The area is a biodiversity hotspot and the conservation of its biodiversity is of both local and international importance. The study employs primary data collected through key informant interviews and questionnaire surveys. It also analyses data from landscape performance assessment by key stakeholders and future visioning by local farmers. The study reveals that the most common concerns in the communities are water scarcity, insufficient quantities and quality of food, diseases, lack of employment opportunities, soil erosion and adverse effects of invasive alien plants. Our results show that households headed by females and those headed by males equally experience problems of food shortage and poor diet (91% females and 90% males), scarcity of medicinal herbs (30% females and 31% males) and illness (80% females and 81% males). There were no significant differences between genders with regards to biodiversity-related problems experienced at household level. With regards to the perception of landscape performance, there were no significant differences in the scores by the youths, men or women (Kruskal-Wallis rank sum test, chi-squared = 0, df = 2, p = 1.00). Thus, age and gender had no influence on evaluation of landscape performance. After an analysis of the community's concerns and vision for the future we conclude that stakeholder-driven ecoagriculture implementation is a climate-smart way to deal with the communities' concerns and achieve the future goals with the overall effect of improving human livelihoods and the local environment.

19. Analysing constraints to the improvement of cattle productivity via trypanosomosis treatment in West Africa

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The economic benefits of removing trypanosomosis from cattle have been mapped for West Africa (Shaw *et al.* 2006) and East Africa. A study commissioned by ILRI in 2013 built on this work by quantifying the effects of disease removal on the greenhouse gas emissions arising from the cattle systems. It found that for most systems, disease removal led to an increase in production and a decrease in the emissions intensity per unit of protein produced of between 2% and 8%. The main drivers of the decrease in emissions intensity were the increases in milk yields and calving rates. While the results indicate that removing trypanosomosis could reduce emissions intensity, the analysis is based on the assumption that the full health benefits of disease removal can be realised, *i.e.* that there are no other constraints. In reality other factors such as feed availability, supply chain capacity and environmental stresses may prevent the benefits from being fully realised. The present study builds on the previous study by developing the approach and analysing one of the key constraints (feed availability) to determine the extent to which it is likely to prevent the theoretical mitigation potential being realised. This project focuses on feed availability, as it is believed to be a key constraint and one where development of approach used in the previous project can provide useful insights.

This project is funded by the International Livestock Research Institute under CCAFS, the CGIAR Research Program "Climate Change, Agriculture and Food Security".

20. Emission of N_2O from soil received saline and sodic water: effects of compost and gypsum applications

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Salt-affected soils, common in arid and semi-arid regions (Pitman and Läuchli, 2002), have been reported in more than 100 countries with a total area of 950 million hectares (Rengasamy, 2006). The objective of this study is to assess the inductive effect of saline and sodic water on N_2O emissions. Thus, a laboratory incubation study was conducted to assess: a) the effects of saline and sodic water on N_2O emissions, and b) monitor emission of N_2O with application of compost and gypsum. The experiment comprised ten combinations of water quality (normal, saline and sodic), N fertilizer (with urea and without urea) and amendments (compost and gypsum). Non saline and non-sodic soils were treated with solution of CaCl2 and NaCl to simulate saline and sodic environment under submerged conditions. Photoacoustic infrared spectroscopy (PAS) technique was used to monitor the flux of N_2O in head space of a cylinder after 1, 6, 11, 17 and 31 days of incubation. Experimental data were analyzed using SPSS statistical package (vs 22), following a completely randomized design (CRD) with three replicates. Means of N_2O-N emissions from soil were compared using Student-Newman-Keuls test. Regardless of urea application, water quality strongly affected N_2O emissions. In comparison with the control, application of saline and sodic water significantly increased N_2O emissions. Regardless of water quality, N_2O emissions were increased significantly with the application of urea. Similarly, application of compost to saline soils also increased N_2O emissions with or without urea. In contrast, application of gypsum to sodic soils reduced emission of N_2O. However, application of urea significantly increased N_2O emissions with or without gypsum. The application of compost enhanced and that of gypsum suppressed N_2O emissions in conjunction with the application of saline and sodic water.

21. Climate-Smart Agriculture livelihood options for displaced population on Yap Island

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Since late 2010, climate-smart agriculture is being discussed and implemented on a global and regional level as a strategy to respond to climate change impacts. Climate-smart agriculture is a unified approach developed by the FAO to develop the technical, policy and investment conditions to support its member nations to achieve food security under changing climate. Its three interlinked objectives such as sustainably increasing agricultural productivity and incomes, adapting and building climate resilience and reducing and/or removing greenhouse gas emissions build location-specific strategies at different levels. Although the concept of climate-smart agriculture has materialized in 2010, many of the approaches behind it were being practiced in the Pacific islands for more than a hundred years. The present study portrays the success story of a group of climate change-induced and climate-change forced migrants relocated to a degraded landscape on Yap Proper. The study explains how a timely agriculture extension intervention program with scientific knowledge and complemented with islanders' traditional knowledge brought fresh promise to about 400 relocated atoll communities over a decade. Given the location-specific nature of climate-smart agriculture and considering the agroecological conditions of the locality, the adopted practices focused on the needs assessments of the targeted community. The program was based on a selection of various climate-smart practices for the displaced population giving emphasis on site-specific needs and stakeholder analysis. Climate-smart agriculture approaches not only provided enough food security but also enhanced the adaptive capacity of the displaced communities which helped them to rebuild a future by transforming a carbon neutral land to a rich biodiverse landscape. The relevance of different climate-smart agriculture practices to the smallholders, constraints of the approaches, need for policy and support services relevant to climate change are discussed.

22. Evaluating the cost-effectiveness of development investments

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Governments and development donors are willing to invest substantial funds in climate-smart agriculture (CSA) practices but are unsure about where such investments will be most effective. Data are virtually always scarce, uncertainties abound, and the effects of social, economic and political drivers on agricultural systems are difficult to quantify. This is the environment in which decisions on CSA deployment must be made.
Faced with similar challenges, many businesses use decision analysis approaches to guide their decisions. We used the principles of such an approach, Applied Information Economics, for projecting the impacts of a water supply intervention in Northern Kenya. The Merti aquifer is to be tapped near Habaswein to deliver clean water to the rapidly growing town of Wajir. Together with project stakeholders, we co-produced an impact model to capture all benefits, costs and risks deemed important. Stakeholders estimated probability distributions for all model variables as inputs to a Monte Carlo simulation of stakeholder-specific decision outcomes.
The intervention appeared risky for all stakeholders, with no certain winners or losers. Critical uncertainties were related to valuation of reduced infant mortality and improved public health, economic feasibility of the water supply operation and the risk of political interference in the project. Guarding against saline water upcoming in the aquifer and an adequate benefit sharing mechanism were identified as design modifications that would raise the chance of project success.
Stakeholders and decision-makers improved their understanding of the decision at hand through involvement in the decision modeling process, which prompted them to make their expectations and assumptions explicit. The procedures used in this study, as well as related approaches such as Bayesian Belief Networks, have great potential to aid in decision-making on CSA practices in the data-scarce environments of the developing world.

23. MAPA project: resilient agro-climatic adaptation models for livestock production systems in Boyacá, Colombia

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The severe social, economic and environmental impacts caused by the rainy season of 2010-2011 showed that the livestock sector is highly vulnerable to extreme weather events (floods, droughts, landslides, etc.). Trends indicate that by 2050, the temperature in some regions of Colombia will increase by between 2 and 4 degrees and some regions will suffer both long periods of flooding as prolonged dry periods. For this reason CORPOICA, with the MAPA Project, (Agro-climatic Adaptation and Prevention Models) is validating climate-smart technologies that economically reactivate livestock production systems and strengthen local capacities to mitigate and adapt to the effects of extreme weather events. Boyacá is one of 18 Colombian departments that have benefited. The municipalities of Sora and Tibasosa were prioritized, with sheep and cattle production systems respectively. Socioeconomic and technical information was collected there by applying structured surveys to producers affected by the rainy season 2010-2011. A participatory workshop was performed with producers, technicians and experts, who together selected three technology options: silage, multinutritional blocks (molasses urea and medicated molasses urea) and Targeted Selective Treatment (TST); these technologies will be tested in an integrated plot respectively in each municipality. Each integrated plot is equipped with an automatic weather station with a rain gauge, anemometer, wind vane, humidity and temperature sensors. The obtained weather data will be integrated into a data logger, which will then be correlated with the results of the evaluation of the animal criteria in each production system, *i.e.* in sheep: weight gain, FAMACHA-test, Eggs Per Gram (EPG) through Macmaster-test, Dag Score; and in cattle: weight gain, milk production, corporal condition and EPG. The aim of this correlation is to elucidate weather patterns that alter the normal functioning of livestock production. Efficient validation of these technologies will provide a software platform web-SAAT (Early Agro-climatic Warning Systems) available for local and national livestock producers.

We thank the "Fondo de Adaptación" for the financial support for this project.

24. Assessing the determinants of adaptation strategies at farm level: the case of wine growers in South-East France

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Understanding the rationale leading farmers to adapt to climate change is a central issue for agricultural economics and policy. It is also a major challenge for water management because one of the strategies to adapt to increasing crop water requirement is irrigation. This will induce new water demands, thus understanding the determinants of irrigation choice is a challenge for robust water planning both in terms of water conveyance infrastructure planning and environmental impacts on water resources. We surveyed wine growers in South-East France (Languedoc-Roussillon) via a detailed Internet questionnaire to understand the determinants of agricultural practices and strategic choices (planting, structural size change, commercialization). We collected data on current and future practices relative to soil-plant water management, perceptions of past economic, regulatory, technical and climate changes and social and economic characteristics. A representative sample of 363 wine growers is used for a descriptive and econometric analysis. 30% of our sample is already irrigating vine while up to 28% is considering this option. When facing a climate change scenario by 2050, 57% of those not currently irrigating say they would implement irrigation. This illustrates the importance of anticipating future demand for irrigation water. We consider two main types of determinants and explore their relative contribution in explaining the adoption of water management practices at farm level. Variables characterizing the terroir are considered (rain, temperature, soil water capacity, elevation) together with socio-economic variables, including main objectives that wine growers are pursuing with their activity (improving wine quality, preserving tradition, etc.). The results show that both terroir and socio-economic determinants play a significant role in the implementation of adaptation actions. Seeking wine quality in production seems to be a determinant of irrigation. We also extrapolate our results to estimate future demand for irrigation water in Languedoc-Roussillon in a context of global changes.

25. Determinants of adoption of climate smart agriculture in coastal Bangladesh

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The benefits of adoption of climate smart agriculture are overwhelmingly stressed in recent time. Bangladesh Climate Change Strategy and Action Plan 2009 has envisaged adoption of climate smart agriculture. This study is intended to achieve a twofold objective: first to assess the status of adoption of climate smart agriculture and second to examine the factors that influence its adoption in environmentally stressed areas. The empirical part of this study was conducted in Dacope Upazila (sub-district) of south-west coastal Bangladesh. Randomly selected 235 households were interviewed through a semi-structured questionnaire during March - June in 2011. From literature review 15 indicators which capture three dimensions of climate smart agriculture such as sustainability of production, resilience to change and potential for mitigation of emissions were used in the questionnaire. Response against each of these was rated in a 5-point Likert scale. Information of various socio-demographic, economic, ecological, and adaptive behavioral characteristics of households and their farms were collected as well. By employing Principle Component Analysis (PCA) technique, weak adopters and strong adopters of the three dimensions of climate smart agriculture are identified. Finally, by employing Multivariate Probit model, the influence of various factors on adoption of climate smart agriculture is assessed. Adoption of sustainability practice is mostly related to farm's size, land types, access to credit, and irrigation facility. The adoption of adaptive measures for resilient agriculture is related with exposure to hazards, past adaptation, social network, and access to NGO's assistance. On the other hand the adoption of measures for reduction of emission is related to cropping practice and farm size. Other factors have very limited influence in this regard. Finally this study came up with few policy suggestions, implementation of which would help the coastal inhabitants to better adopt climate smart agriculture for livelihood and food security.

26. Evolution of soil functional diversity after changes in management practices and effects on N_2O emissions

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The SOFIA project addresses the impact of agricultural practices on the taxonomic and functional diversity of the soil communities and the consequences on the soil functions, particularly regulation of greenhouse gas emissions. The project relies on a long-term environmental observatory (SOERE ACBB) located at Estrées-Mons in northern France, which provides experimental treatments varying crop rotation, mineral N inputs, intensity of tillage and crop residues management.

During the course of a 4-year soil differentiation induced by these practices, agricultural, physical and chemical variables for the crops and the soils were measured either continuously or once a year. The taxonomic and functional diversity of the earthworm, macroinvertebrates, microfauna and bacterial and fungal communities, and the nitrifying and denitrifying communities were determined. The CO_2 and N_2O emissions were continuously measured using automatic chambers.

We observed an early differentiation of the experimental treatments, notably a significant stratification of organic carbon, microbial biomass and enzymatic activities in treatments with reduced tillage compared to conventional tillage. Soil communities' differentiation was less affected by residues management and not affected by N fertilization rate after 4 years. The N_2O fluxes were low (max 2.5 kg N-N_2O over 3 years), with peaks mainly after N fertilization in spring. Differentiation in N_2O emissions was however mainly related to N input, with 2 to 3 times lower emissions with the reduced N fertilization.

Combined evolution of soil communities and N_2O emissions only began more recently but should provide future insight on understanding how GHG emissions are shifted by changes in agricultural practices.

27. Opportunities and challenges in China's irrigation water–energy nexus

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China faces its own 'perfect storm' as rapid economic transition drives increasing per capita demand for water, food and energy. The agricultural sector in China is responsible for nearly two-thirds of total water use and a large proportion of greenhouse gas (GHG) emissions. There are strong interdependencies between water use in agriculture and energy consumption as water saving technologies can require increased pumping, pressurizing and conveyance. The Chinese Government has included water efficiency improvements and carbon intensity reduction targets in the 12th Five-Year Plan (5YP, 2011-2015). Water pumping is a major input for Chinese agriculture, yet the links between energy use and irrigation modernization are not always addressed in policy targets. Here we develop linked resource analysis to assess the consequences of sectoral policy targets: to identify win-win outcomes which achieve water and energy savings, and on trade-offs; in which reduced water application leads to increasing GHG emissions. We analyse water use efficiency and energy use using scenarios based on targets in the 12th FYP, nationally and in four provinces with contrasting water-energy endowments. We find that expansion of sprinklers and micro-irrigation as outlined in the 5YP could increase GHG emissions nationally from agricultural water use. The provincial level results show that water supply configuration (balance of surface and groundwater) largely determines the potential energy savings from reduced water application.

28. A climate smart strategy to reduce risks and increase resilience of agricultural production systems in Colombia

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More than 1 million ha devoted to food production in Colombia were severely affected by La Niña event in 2010 and 2011. This demonstrated that small farm production systems located in marginal areas of Colombia are extremely vulnerable to climatic hazards and that they require climate smart information and technologies to reduce impacts on food production and livelihoods. A multi-disciplinary and multi-institutional team of researchers led by the Colombian Agricultural Research Institution, CORPOICA, joined efforts in 2013 to contribute to the economic recovery of areas affected by La Niña, by developing and assembling information on climate risks and adaptation responses at local and regional level in user friendly decision support system. The main purpose is to empower local extension services and small farmers with agroclimatic information and tools to plan adaptation responses for 54 production systems to future climate extreme events. The team analyzed 29 years of climate data series to identify spatial and temporal susceptibility of land to climate hazards (floods and droughts) associated to El Niño/Niña events in 12 departments of Colombia and identified 36 crop production niches with lower risks of water deficits/excess based on soil-plant-climate parameters. Simultaneously, the team compiled 900 documents on management options with potential to solve water excess/deficits and conducted 1400 rapid rural appraisals to characterize biophysical and socioeconomic constraints and to identify local perception to climate hazards and adaptation responses. Promising adaptation technologies for specific production systems are under field evaluation by local stakeholders in pilot sites. Knowledge and information generated in the project is being shared by more than 400 extension agents.

Acknowledgements: Fondo Adaptación for financial support to carry out project activities

29. Interpretation of GHG emissions from mixed crop, grassland and ruminant systems using the FarmSim model

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Agricultural activities are responsible for more than 10% of total anthropogenic GHG emissions, contributing 13% of CO_2 and over 70% of N_2O. To mitigate these emissions a variety of agronomic practices can be adopted. The most noticeable options are tillage and plant residue management. The aim of this work is to evaluate the effect of tillage after 20 years of permanent grassland in terms of N_2O and CO_2 emissions. We assessed the emissions with simulation modelling and compared the results to direct measurements. The model, FarmSim, is a simulation framework allowing the description of a mixed crop, grassland and ruminant system and calculating the losses from the biogeochemical cycles at field and regional scales. GHG emissions from grasslands are internally calculated by the grassland-livestock model PaSim, while a subsequent and automatic parameterisation of the crop model CERES-EGC allows simulating tillage operations, biomass incorporation and the emissions from arable lands. The case study was carried out at the SOERE-ACBB (Lusignan, FR) in a 20 year grassland. N_2O and CO_2 had been measured since 2008 and were assessed in particular detail before and after the tillage operations that occurred in April 2014. The results highlight the adequacy of the FarmSim model to quantify the amount and the temporal dynamics of N_2O and CO_2 emissions from stable grasslands over different managed years. Similarly, tillage operations have been well described in terms of evolution of the gaseous exchange in soil and atmosphere. Compared with the no-tilled surface, tillage altered CO2 emissions and stimulated the N_2O released (3.27 mg N-N_2O m^{-2} in no-tilled grassland and 37.28 mg N-N_2O m^{-2} in tillage surface in a 42 days period across the tillage). We conclude that tillage and residues incorporation cause a general increase in N_2O when compared to no-tillage practices.

This study was financed by ADEME (French Environment and Energy Management Agency) in the project AEGES (Attenuation of Greenhouse Gas Emissions in Grasslands).

30. DAYCENT parameterization and uncertainty assessment for modelling Swiss crops

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The identification of sustainable greenhouse gas (GHG) mitigation options through the use of a comprehensive decision making tool integrated with biogeochemical models requires accurate predictions of crop productivity and soil organic carbon (SOC) stock. DAYCENT is a daily version of the well-known CENTURY ecosystem model. The model simulates all major processes that affect soil C and N dynamics, including plant production, water flow, heat transport, SOC decomposition, N mineralization and immobilization, nitrification, denitrification, and methane oxidation. Simulated plant productivity is a function of genetic potential, phenology, nutrient availability, water/temperature stress, and solar radiation. The accuracy of the model predictions under specific soil and climatic conditions depends on the validity of its parameterization to field observations. This study focuses on parameterizing the most common crops in Switzerland, such as winter/summer wheat, rye, winter spelt, winter/summer barley, maize, field beetroot, rape, potatoes, sunflower, winter peas, soybeans and white cabbage. The 10 most sensitive crop growth parameters for each crop were parameterized using an inverse modelling technique. Data on crop productivity (yields, aboveground biomass) and SOC were obtained from three long-term experiments in Thervil (1977-2013), Frick (2003-2013), and Changins (1971-2013), where several agricultural input systems (organic, biodynamic, conventional with and without manure additions) and soil management options (full and reduced tillage) have been evaluated on crop productivity and SOC change. Model parameterization was evaluated against independent proportion of the data and the effect of parameters uncertainty on crop productivity and SOC predictions has been evaluated using the Monte Carlo approach. The approaches to crop parameterization and these results could be applicable to other DayCent modelling studies under Swiss conditions.

31. The yield response of intercrop system to rainfall changes on the southern slopes of Mt. Kenya in Embu

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Rainfall variations on the southern slopes of Mt. Kenya in Embu, occasioned by climate change often lead to considerable yield losses in small-holder farms especially when sole-cropping is practiced. To test the yield response of an intercrop system to the changing rainfall, data was collected from two intercropping experiments in Kenya Agricultural Research Institute, Embu (0370 53.27'E, 000 33.18'S and 1,420 meters above sea level). In the first experiment, the intercrop involved four morphologically contrasting Zea mays varieties (DK8031, KH500Q, PHB3253 and KDV1) with similar bean variety Embean14, while in the second experiment, four different Phaseolus vulgaris varieties (Embean14, GLP585, GLP×92 and Embean18) were intercropped with maize variety DK8031. The experiment was laid in randomized complete block design with split-plot arrangement, where sole-crop or intercrop system was allocated the main plots and varieties were set in the sub-plots. The study spanned three seasons; 2011 short rains, 2012 long rains and 2012 short rains. Rainfall reduced by 31.9% from first to second season resulting to 21.6% and 29.9% decrease in Z. mays and P. vulgaris yields respectively. Rainfall increased by 27.9% from the second to the third season of the experiment, confirming the erraticism of rainfall in Embu. In general the rainfall variation across the three seasons was highly significant (P=0.05). The sole-crop yield varied significantly (P=0.05) but the land equivalent ratios of the intercrop in three seasons were not significantly (P=0.05) different, indicating intercropping resilience to rainfall changes and a chance for farmers to benefit more from same piece of land. Intercropping varieties PHB3253 and Embean14 resulted in higher (P=0.05) yield than others. It was concluded that intercropping enhanced by continuous selection of varieties may be a vital approach of mitigating rainfall changes risks in Embu small-holder farms.

Acknowledgement: CIMMYT-SIMLESA and KARI for the financial and data collection support.

32. Rain water harvest technology as a tool for climate smart agriculture for small holder farmer in Bangladesh

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Bangladesh is primarily an agrarian economy. Agriculture is the single largest producing sector of the economy since it comprises about 18.6% (data released on November, 2010) of the country's GDP and employs around 45% of the total labor force (CIA - The World Factbook). The performance of this sector has an overwhelming impact on major macroeconomic objectives/indicators like employment generation, poverty alleviation, human resource development and food security. Bangladesh achieves a position of being able to produce enough rice not only to meet its food, feed, and seed requirements, but also to be left with some exportable surplus. Yet, the agriculture sector is extremely vulnerable to disaster and climate induced risks. Climate change is anticipated to aggravate the frequency and intensity of extreme weather events in Bangladesh (Xenarios *et al.* 2013). Drought is one of the major problems for the agriculture and its development in the country. It is a slow extermination which can last for number of days to several years with a devastating effect on the agricultural production and livelihood of the people (Saadat *et al.* 2009). There are some regions in Bangladesh where every step of agriculture from field preparation to ripening of crops is dependent on rainfall (Alam *et al.* 2011). Consequently, drought affects annually 2.5 million ha in kharif (wet season) and 1.2 million ha in dry season (Mondal 2010). Therefore, drought management in agriculture is a major challenge for Bangladesh in achieving sustainable agricultural development. To tackle the drought efficiently it is essential to understand the spatial-temporal pattern of drought in Bangladesh and adaptation/mitigation measure. Water is a natural resource with spatial scarcity and availability. Additionally, cross-country anthropogenic activities (Barrage/Dams on the upstream) caused a severe negative impact on water resources and eco-systems of Bangladesh in the recent years. The rivers and canals dry up during the dry season and make the people completely dependent on groundwater. Accordingly the contribution of groundwater as a source of irrigation has increased and surface water has declined. It is now inevitable to look for alternate water sources for agriculture. Water harvest technologies (WHTs) can play an important role in this regard. WHTs can provide an additional source of water for crop production at the most critical stages of the growing season, thereby increasing yields and food security. Specific WHTs for an agricultural region need to be identified based on its potentiality. Appropriate water harvest technology and its up-scaling could contribute to sustainable agriculture.

33. Greenhouse gases emission efficiency of alternative tillage practices in wheat farming systems of Bangladesh

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The greenhouse gases (GHG) emission efficiency (GEE) of conservation tillage (CT) at scales higher than the field plot is inadequately examined by researchers. As the economy of Bangladesh is heavily dependent on the agricultural sector, which is dominated by marginal farmers, linking farmers to practices that mitigate GHG emissions and improve production efficiency could have significant economic and environmental benefits. The impacts of CT in wheat cultivation on GEE are assessed using primary data [N=328] from Eastern Indo-Gangetic Plains (EIGP) of Bangladesh, employing a non-parametric efficiency estimation method. Significant differences in emission efficiencies are observed between CT adopter, and non-adopter farms using traditional tillage (TT). Among the CT options, power tiller operator seeding (PTOS) achieved the highest GEE score (0.92), followed closely by strip tillage (ST; 0.91), and bed planting (BP; 0.90). Currently, ~0.45 million hectares are under conventional wheat cultivation in Bangladesh. Our estimates show that a reduction of approximately 162 Kg CO_2 eq. ha^{-1} in terms of GHG emission (mainly by input optimization of fossil fuel and fertilizers) is possible with CT adoption in wheat production. Hence, the expansion of CT wheat in Bangladesh could reduce emissions to the extent of approximately 0.07 megatons CO_2 eq. ha^{-1} during each wheat growing season. Drawing on the higher GEE of CT (0.91) compared to TT (0.68), a further analysis is carried out using a fractional regression model. Results show significant influence of farmer education, the proximity of farms to a main road, training and experience on conservation tillage and split application of inorganic fertilizers on the GEE of studied farms. The practice of specific principles of CT, relative to TT, particularly crop residue retention in the field, limit the full adoption of the technology in the EIGP to some extent, due to their removal and use as cooking energy and feed.

34. Enabling synergies between development, climate change and conservation through land use practices portfolio approach

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Climate change has become one of the pressing challenges of our time and the global community through the commitments from the national governments is trying to address it. With its crosscutting nature, efforts to address climate change within the sectorial policies and practices by seeking potential synergies are growing. However, there is a considerable knowledge gap as to which practices could actually lead to effective and efficient measures that can address the multiple needs at particular scale in the land use sector such as a landscape. Studies on synergies reveal that it leads to effective and efficient strategy to address multiple compatible functions at a time when the necessary enabling conditions are in place. The effectiveness is of great importance particularly from the fact that, for example, in agrarian communities in developing countries, there is a competition for the limited available pieces of land constrained by the sharply increasing human and livestock population and intensive utilization, leading to degradation. The efficiency aspect is also of utmost importance due to the fact that land use sectors in developing countries are generally resource-limited both financially and technically. We use a portfolio approach to identify and characterize measures/practices that could promote the integration of development, climate change and conservation in the land use sector. Doing so will ease the adoption of practices with strong potentials of meeting multiple objectives and hence help to address multiple problems. Such approaches could also simplify the policy prioritization and decision-making processes concerning the promotion of practices with potentials to meet multiple functions *i.e.* cater for local demands, facilitate the implementation of national policies and help in fulfilling the international commitments of the countries.

35. Coffee agroforestry systems in Peru – a double dividend for biodiversity and small scale farmers?

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Tropical agroforestry is seen as a promising approach to reconcile biodiversity conservation and food security as it holds the potential to increase overall productivity, resilience and sustainability, and meanwhile provide a refuge for biodiversity. Evidence of these double benefits is however lacking, as multidisciplinary studies to quantify both biodiversity- and socio-economic performance are rare. Therefore, in this study we quantified the possible trade-offs between biodiversity performance and socio-economic performance of small-scale coffee plantations and identify opportunities for resilience. We conducted interviews amongst 150 farmers and collected farm data for a variety of small-scale conventional and agroforestry coffee management systems in San Martín, Peru. This is a landscape directly faced with the threats of climate change and deforestation. Our database includes information on: I) vegetation characteristics, *e.g.* canopy closure and DBH; II) costs, *e.g.* labour and chemicals; III) benefits, *e.g.* coffee yield and income from other products; IV) management characteristics, *e.g.* use of chemicals and weeding; and V) tree and butterfly biodiversity, with natural forest as reference. Regression analyses were conducted to test the effect of different management systems on biodiversity and economic performance. We measured economic performance with Benefit-Cost Ratio (BCR), biodiversity performance with a combined Shannon index, and management and vegetation structure with the comprehensive Management Intensity (MI) index. Effect of MI on economic indicators, *e.g.* coffee price sensitivity, stability of food production and income, and ecological indicators, *e.g.* aboveground carbon stock and temperature, was analysed to measure resilience. Our results show a significantly higher biodiversity performance for agroforestry systems compared to conventional systems, as well as a positive BCR and increased resilience. These findings suggest that agroforestry coffee plantations show large potential to combine biodiversity conservation and local development and at the same time increase overall resilience.

36. Soil carbon input by below- and above-ground biomass in rainfed cropping systems in the highlands, Madagascar

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Agricultural soil could be a major sink of carbon with appropriate cropping system and soil management. This study aimed to evaluate the potential of CA cropping systems to store carbon into soil from belowground biomass. Three cropping systems were compared: (1) rotation of upland rice followed by maize intercropped with *Crotalaria grahamiana*, with no tillage (R-MC_NT), (2) rotation of rice followed by oat (*Avena sativa*) intercropped with vetch (*Vicia villosa*), with no tillage (R-OV_NT), and (3) rotation of rice followed by maize intercropped with common bean, with conventional tillage (R-MB_CT). The two components of the rotation were cultivated each year. Maize, rice, crotalaria, common bean, oat and vetch were fertilized with 5 Mg ha^{-1} of "improved" manure. The experiment was conducted in a research station. Hénin & Dupuis model was used to simulate the change of soil carbon content according these three treatments. Compared to the total carbon input by both above- and below- ground biomass, 29%, 34% and 46%, so 1.40, 1.70 and 1.14 Mg ha^{-1}, were attributed by plant roots, for R-MC_NT, R-MB_CT and R-OV_NT systems, respectively. Simulations in 20 years showed higher increasing of carbon stored with R-MC_NT system (from 71 to 84%).

37. Climate Smart livestock development in natural and improved savannas of an extensive ranch in central Africa (RDC)

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In the Central African extensive livestock systems improved management practices and technologies can deliver a significant portion of the Climate smart efforts needed (FAO 2014). The "Kolo" ranch is located 14°45' - 15°00' E, 5°15'- 5°52' S (Bas-Congo, DRC). 20 000 N'dama cattle heads are managed for a production of 1200 tons live weight (LW) on 50 000 ha: 47 500 ha of natural "Hyparhenia" savanna (NS) and 2 500 ha of Brachiaria improved grasslands (BiG). Farm gate LCA methodology and IPCC references were contextualized to the local practices to estimate the level and diversity of non-renewable energy (NRE), GHG emissions and economic efficiencies of the system. The results show an overall NRE consumption of 6 259 MJ t LW^{-1} $year^{-1}$. The system based on abundant pasture resources and fire use to stimulate regrowth in NS, using very few inputs and light infrastructures, is low consumer of energy. GHG emissions are important: 30 t CO_2-e t LW^{-1} exported, biomass burning and enteric emissions shares are 50% and 36% respectively of the emissions. On the ecologically intensified surfaces (BiG) of the ranch, where fire use is strictly avoided and where the finishing animals are concentrated, performances are increased due to biomass and forage quality improvement, the carrying capacity is raised from averages of 0,41 on (NS) to 4,51 TLU / ha on (BIG). The annual LW gain per ha is in proportion 12 vs 254 kg ha^{-1}. Related to meat production, we observe a lower energy consumption 7 978 and 4 405 MJ/ton LW Gain and GHG is reduced 51,7 and 8,5 t CO_2-e t of LW Gain on average NS and BIG surfaces respectively. The production costs are 2,14 and 1,23 €/Kg carcass eq. LW gain for NS and BIG surfaces respectively. In such tropical environments and livestock systems, grassland improvement and changes of management practices are very probably the most effective Climate smart investments to mitigate climate impact contribution and improve environmental and livelihoods efficiencies.

38. Targeting CSA in Southern Tanzania under multiple uncertainties

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Uncertainties in future climate, costs and benefits of climate-smart agriculture (CSA) practices, and in the way socio-ecological conditions affect CSA outcomes, limit efficient and effective scaling of CSA across sub-Saharan Africa. These uncertainties are usually neglected in planning processes because of the technical, logistical, and practical challenges they present. Here we report on a computationally rigorous framework for targeting and prioritizing CSA practice selection under multiple uncertainties. We developed a Bayesian Belief Network based on the livelihoods framework, parameterized by both hard data and expert knowledge, to predict the range of plausible outcomes from CSA adoption in a spatially explicit way. At the request of the Tanzania Ministry of Agriculture, Food Security, and Cooperatives (MAFSC), we then applied the model to optimize investment decisions for small-scale technologies to increase water-use efficiency (drip irrigation, micro-catchments, etc.) in the Southern Agricultural Growth Corridor of Tanzania (SAGCOT) to help operationalize Tanzania's Climate Change Resilience Plan. With stakeholders in the region, we calibrated the model to local socio-ecological conditions. Then using GIS and survey data, we evaluated the spatially explicit model for five water use technologies selected by the MAFSC. In the topographically and agriculturally diverse SAGCOT, adaptive and livelihood benefits from water-use interventions varied across space. For example, low-input technologies such as zai and chaco pits were more suitable for smallholders than for commercial farmers. However, even for interventions that have potential for large benefits in one outcome, there was always a non-negligible probability of negative outcomes in other dimensions, highlighting the critical need to incorporate uncertainty and risk when planning CSA implementation to achieve desired development outcomes.

39. Opportunities and limitations of emissions intensity as a metric for climate change mitigation from the livestock sector

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Global food demand is expected to increase by 50-60% by 2050 due to global population increases and socio-economic development, with an attendant increase in direct agricultural greenhouse gas emissions by about 30%. Given those trends, reducing emissions from countries where agricultural emissions make up a substantial portion of their national total is challenging, and particularly difficult for countries where ruminant livestock play a dominant role, given the limited options to reduce absolute emissions without reducing overall livestock production. The considerable variation within and between countries in the efficiency of animal production implies that setting limits on absolute emissions at the national level could perversely result in net global emissions increases, if curtailing production from high-efficiency producers simply shifts production to lower-efficiency producers. Consequently, many countries and international organizations focus increasingly on reducing the emissions intensity of livestock production, *i.e.* reducing the quantity of greenhouse gases emitted per unit of product. This, it is argued, provides a better measure of countries' efforts to reduce their contribution to climate change while allowing them to satisfy the growing global demand for livestock products. Here, we critically review the justifications and limitations of emissions intensity as a measure for achieving mitigation outcomes in livestock systems. We consider differences and similarities with other sectors that serve critical human needs, global patterns of livestock production, consumption, trade and resulting risk of leakage, and the importance of livestock emissions in scenarios of stringent global mitigation. We find that emissions intensity can indeed serve as a useful metric to measure progress towards mitigation outcomes, but careful attention is required to reductions in emissions intensity projected even under business-as-usual, and the wider context of new mitigation practices, demand-side management, improved trade mechanisms, and integrated land-use planning to maximize carbon sink opportunities.

40. Climate smart agriculture from field to farm scale: a model based approach for Southern Africa

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Southern Africa (SA) is expected to be particularly impacted by climate change projecting a 40% decrease in rainfall in critical areas over the next 70 years and maize productivity falling by up to 30% by 2030. The high variability in agro-climatic conditions, farming systems and rural livelihoods in SA represents a challenge in the generation of locally adapted climate-smart cropping systems. To explore and test adaptation strategies to climate change at the farm level, and to assess the role of alternative maize-based cropping systems, an interdisciplinary approach was developed that consists of loose coupling of cropping systems and farm household models. Using data from long-term agronomic field trials, the crop growth model APSIM was calibrated to simulate a wide range of maize-based cropping systems for different agro-ecologies and climate change scenarios. At the farm household level, the efficient frontier analysis was used to identify efficient farming systems which minimize their inputs utilization and negative externalities (erosion and greenhouse gases) and at the same time maximize their production. Our approach takes advantage of the prediction potential of field-scale models to generate thousands of simulated maize based cropping systems, and an optimization method to benchmark farm-level performance and eco-efficiency. Compared to common linear programming methods (*e.g.* profit maximization), we simulate more sophisticated farmer's strategies (*e.g.* trade-offs between market sales and food self-sufficiency, between use of crop residues for soil fertility and animal feed) based on data from a 500 farm household survey recently conducted in SA. This framework, taking into account long term cropping systems effects and efficiency frontier analysis at the farm scale, allows identifying practices and pathways for climate smart agriculture in this vulnerable region.

41. Mainstreaming climate smart agriculture practices through climate smart villages: scalable evidences from South Asia

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Since the impact of climate change induced variability is complex and has local-level causes and effects, the solutions are not simple and require locally-adapted practices with real-time decision making by the farming households/community. Such climate smart agricultural practices (CSAPs) need to be developed, adapted and targeted to relevant farm typologies in order to reach scale and impact. The climate smart village (CSV) model, a community-based approach to sustainable agriculture provides common platform to researchers, extension agents, local governments, farmers groups, private sectors and the service sector to collaborate and identify the most appropriate CSAPs to tackle local challenges related to climate change. Such a model enables CSAPs to be integrated into village development plans so that they benefit from local knowledge, converge with local government schemes and ensure collective action. This contribution describes the development and mainstreaming of CSAPs through engaging local community and establishment of CSVs with multi-stakeholder collaboration. This also documents how the CSV model can achieve scaling CSAPs in smallholder systems of South Asia. In CSVs, a portfolio of CSAPs adapted to local farming system is adopted by the community for multiple benefits of increased productivity, income and resilience to climatic variability. For example layering of no-till maize-wheat rotation with residue recycling, inclusion of legume and site-specific nutrient management enhances yield (2.35 t/ha/yr) and income (USD 941/ha/yr) along with resource conservation benefits. These evidences coupled with community-based adaptation components of CSVs contributed to the expansion of CSVs from 7 in 2012 to 60 in 2014 across south Asia. This also led to government buy-in for scaling CSAPs, for example government of Haryana, India. The CSV model demonstrates strong scalability through unique and interrelated elements of CSA-led business cases, innovation platforms, knowledge networks, ICTs, gender and youth empowerment; thereby facilitates convergence of AR4D programs.

42. Towards a scalable framework for evaluating and prioritizing climate-smart agriculture practices and programs

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Governments, donors, and non-governmental organizations are recognizing the need to integrate climate change and agriculture development goals in planning. Incorporating the climate-smart agriculture (CSA) concept can strengthen integration by explicitly emphasizing tradeoffs between investment options. Given the complex relationships between the food security, adaption, and mitigation goals of CSA, decision-support frameworks are needed that integrate stakeholder priorities, draw on the best scientific evidence available, and present complex results simply. Here we present a four phase stakeholder-driven framework for prioritizing CSA investment, designed to be globally applicable, for various users, for use from regional to sub-national levels, and adjustable given data and resource constraints. In the first phase, the scope and next-users of CSA portfolios are clarified, relevant practices are identified, and roughly ten indicators are selected/adapted from a suggested set of 29, based on scientific literature, to evaluate practices against CSA outcomes. A participatory workshop is used in phase 2 to short-list practices based on the results of the indicator evaluation and additional stakeholder criteria. A cost-benefit analysis is then conducted (phase 3) on these priority practices. In phase 4, stakeholders are reconvened to develop CSA investment portfolios that minimize trade-offs, maximize benefits and synergies, and address end user priorities. Barriers to adoption of practices and pathways to overcome these are used to adjust priorities or implementation plans. We present lessons learned from Guatemala and Mali, which demonstrate the scalability of the process, modifications based on institutional contexts, and strategies for refining the framework for use in Africa and Asia in 2015 with users including national agriculture ministries, agriculture development alliances, and bilateral and multilateral donors.

This research was principally funded by CCAFS.

43. Repeated inputs of organic matter in the long term protect soils from global changes

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In the suburban area of Dakar (Senegal), family smallholdings produce market gardening sometimes for several decades. Dior soils (arenosol) and Deck soils (fluvisol, calcareous with high clay content) are intensely cultivated and required frequent applications of organic matter (OM). The objective of this study was to assess whether long-term changes in chemical and physical properties of these tropical soils increase or reduce the yields and the vulnerability of these family smallholdings to global changes. After field surveys, we collected Dior soil (Dr) and Deck soil (Dk), cultivated for fifty years (50), and named Dr50 and Dk50 respectively, and nearby, the same soils, but which have never been cultivated (0), and named Dr0 and Dk0 respectively. On these four soils, we cultivated three successive cycles of lettuce and compared an optimum mineral fertilization (T1) with two types of OM, a sewage sludge and a poultry droppings, with the amounts corresponding to 50% (T2) and 150% (T3) of the nitrogen equivalent of T1. Before the experimentation, the cation exchange capacities and the initial concentrations of organic carbon and total phosphorus were significantly higher between both pairs of soils, Dr50 and Dr0 soils and between Dk50 and Dk0 soils. The structural stability of the Dr50 and Dk50 soils were respectively better than Dr0 and Dk0 soils. After each crop cycle, yields were higher (i) for Dr50 and Dk50 soils, respectively than for Dr0 and Dk0 soils, (ii) with input of poultry droppings rather than sewage sludge and (iii) for doses T3 as T1 and T2 respectively. These results showed that these two types of tropical soils, even if they were intensively cultivated for a long time, have acquired some protective physical and chemical characteristics and were better adapted to global changes mainly due to OM inputs in the long term.

44. The use of agroforestry practices by dairy farmers in Malawi

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Adoption of agroforestry practices could be a useful approach to increase food security and improve rural livelihoods while helping poor communities to adapt to climate change. Agroforestry also has a strong potential to reduce greenhouse gas emissions. For livestock farmers, agroforestry can provide an important source of feed for cattle in times when little other choice is available. For a number of years, Malawi has been promoting the use of agroforestry, and its importance has been highlighted in several policy documents, with various agroforestry pilots and programmes being implemented across the country. This study investigates the current adoption levels of agroforestry practices by dairy farmers in Malawi, using data from a nationwide smallholder survey. Statistical Programme for Social Sciences (SPSS) was used to assess the relationship between a number of household socio-economic and external characteristics – including security of tenure, access to extension, total income, gender and level of education of the head of the household – on the adoption of agroforestry. Additionally, we examined the types of agroforestry systems practiced and the main benefits of trees grown in these systems. The main findings demonstrate that adoption rates are low, with only 40% of respondents being involved in agroforestry work. The most common system adopted is intercropping (46.4%), followed by hedging (34.8%) and alley cropping (13.3%). Surprisingly, the results display no correlation between most of the farm and external variables and the likelihood of adoption. Key challenges constraining the uptake of agroforestry practices as reported by farmers are a lack of knowledge of the benefits of agroforestry, a lack of seeds, and limited land for planting. We conclude that a targeted training campaign on the benefits of agroforestry as well as a timely provision of seeds are the two factors that could most likely increase its adoption potential.

45. Towards climate-smart dairy value chains in Tanzania

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The gap between milk demand and local supply in Tanzania is very large and is projected to continue to widen in the near to medium future. This unmet demand presents an important opportunity for improving the welfare of producers and their market agents, through income and employment generated in dairy production, processing and marketing. In this context the CGIAR Research Program on Livestock and Fish embarked on an effort to transform the Tanzanian dairy value chain (VC) to produce more milk by and for the poor. But efforts to maximize milk yields, production and profitability need to be balanced with long-term sustainability and environmental stewardship. It is thus important to assess potential environmental impacts before embarking on large-scale development projects geared towards livestock production intensification and value chain transformation. Here we present the application of the CLEANED framework for environmental ex-ante impact assessment of livestock and fish value chains to the Tanzanian dairy VC. We assess the environmental sustainability in terms of water, soil and biodiversity as well as GHG impacts of four best-bet intervention scenarios for adaptation to climate change and increased milk production: (i) introduction of improved breeds, (ii) improved animal health, (iii) improved input and output markets, (iv) reduced seasonality of feed availability. Productivity increases in all four scenarios go hand-in-hand with increased resource-use efficiency. Absolute increases in natural resource use on the other hand point to the need for *e.g.* appropriate manure and soil fertility management. Also, an overall rise in GHG emissions is expected. Through providing rapid results and flagging the main environmental issues simultaneously, we aim to support evidence-based discussions of alternative development pathways in the Tanzanian dairy value chain.

46. Adapting pest management practices in sub-Saharan horticultural cropping systems in the context of climate change

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The Horticultural Systems (HortSys) research unit of CIRAD undertakes with its partners in Sub-Saharan Africa, agroecological research which aims to: (i) locally manage plant health risks sustained by fruit and vegetable producers, which are exacerbated by climate change (CC), in view of adapting cropping systems to its effects; (ii) adapt crop protection practices in order to mitigate CC at the global scale; (iii) prevent / anticipate the introduction / establishment in Europe of exotic pests that have become potentially invasive due to CC, by better management of the same in the areas of production of export crops.
For instance, with the optimization of food webs involving Bactrocera fruit flies associated to fruit tree orchards in West Africa, all the above three aspects are encompassed since: (i) CC is likely to impact established biological control by de-regulating interactions between natural enemies and pests, due to greater susceptibility of higher trophic levels to CC effects; (ii) availability of a low-cost natural protection option will prevent fruit producers from cutting their trees, thus avoiding carbon destocking; (iii) Bactrocera fruit flies have become quarantine pests in Europe where they now may establish due to CC.
Similarly, with "insect nets" which are increasingly used for protecting vegetable crops against arthropod pests, both in Eastern and West Africa: (i) microclimate under nets is likely to be modified by CC, which will require site-specific adaptations (*e.g.* highlands of Kenya *vs*. lowlands of Benin, where nets may have either a positive or negative impact on crop physiology and fungal plant diseases); (ii) the use of physical barriers drastically reduces losses and thus useless investment in chemical fertilizers and pesticides with high carbon footprints; (iii) the quarantine status of several vegetable pests, *e.g.* the whitefly *Bemisia tabaci*, has been altered by CC.

47. Promoting Climate Smart Agriculture in Nigeria: Household strategies and determinants among farmers

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The necessary evidence-based information required by farmers for improved sustainable food production is not always at their disposal. This reduces the ability to monitor and manage water resources in adapting to climate change. Climate-induced reductions in crop yields are expected to have significant long-term effects on the GDP of Nigeria. The study assessed climate change adaptation strategies among all the participating farmers across the 30 selected schemes under the River Basin Development Authority in Nigeria. Both participatory and climate analogue methodologies were adopted for the study. Fostering linkages with research and meteorological agencies for timely information on new drought resistant crop varieties and weather forecasts was observed to be of utmost important and as adaptation strategy. To implement climate-smart agriculture there is need for competence-building learning system among small holder farmers. Achieving climate smart agriculture in Nigeria requires the building and strengthening the network of actors involved in the system of innovation.

48. Climate forecast, sustainable land and practices management, useful tools for implementation a climate smart village

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To find solutions to the needs of a sustainable agricultural development that can ensure food security, improve the livelihoods of poor smallholder producers in the context of changing climate, some options of "climate smart agriculture" are being tested in two villages in Kaffrine, based on the concept of climate smart village. The different components of this model are climate services, weather insurance, diversification, mitigation/carbon sequestration, community management of the resources and capacity development. A holistic approach combining researchers, local partners, farmers' groups, have permitted to select, prioritize and test the best climate-smart technologies and approaches that are suited to local conditions. The entry point of the work is the forecast information sharing and use to plan the cropping activities at the beginning of each rainy season. Based on this forecast a range/combination of activities are being tested to ensure food security, promote adaptation and build resilience to climatic stresses in two sites with the hope that proven approaches can be scaled up to the rest of the country. The tested combinations include sustainable management practices, improved varieties, rotation with legumes, soil and water conservation techniques. Nutrient management are optimized through fertilizers application precision. Residue management and shrub are used to enhance carbon storage. Several practices emerge as double or triple wins in terms of climate adaptation, carbon sequestration, and productivity. In particular, changes in crop production associated with climatic forecast, integrated soil fertility management feeding are shown to provide multiple benefits across research villages. Despite the promising results of this new program, the main challenge remains dry spell, for which water conservation and management through water ponds building and supplementary irrigation may constitute a viable alternative in these semi-arid zones.

Work funding by CCAFS.

49. Characterization of biochar properties derived from willow plant biomass for carbon sequestration and agricultural use

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Biomass utilization for production of biochar (used as a soil amendment), which enhances soil fertility and carbon sequestration, has gained widespread attention. The understanding of biochar's physical and chemical properties is needed to use it for specific purposes such as nutrient retention, pH amelioration or contaminant remediation. Willow plant biomass was pyrolyzed at 300, 500 and 700 °C temperatures using fix-bed pyrolysis reactor. The bio-char yield decreases from 41.23 % at 300 °C to 24.35 % at 700 °C, whereas increasing pyrolysis temperature from 300 °C to 700 °C yielded bio-gas from 19.92 to 34.82 %. Maximum bio-oil yield (40.93 %) was obtained at 500 °C pyrolysis temperature. The biochar pH, EC, C, K, Na, ash content, and basic surface functional groups increased while acidic, carboxylic and elements P, Ca, and Mg decreased with increasing temperature. The highest surface area (5.25 m^2/g) and CEC (6.70 cmol/kg) was observed at 300 and 500 °C respectively. The atomic ratios O/C, H/C and (O + N)/C decreased with temperature indicated aromatic carbon at high temperature. The analyses of Fourier Transformation Infrared (FTIR) show in decrease of organic functional groups with increasing temperature. It was found that the bio-char products can be characterized as carbon rich source at high temperature, which can be successfully used for carbon sequestration and agricultural use. These primary results could be useful meaning for utilization of willow plant biomass for biochar as well as for bio-energy production.

50. Assessing mitigation potential of agricultural practices in tropical, developing country systems

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Developing countries contain up to 70% of the technical potential for AFOLU-based mitigation. With the promise of public and private incentives for mitigation, dozens of 'greenhouse gas (GHG) calculators' have been developed in the past decade to provide farmers, companies, governments, and carbon markets with tools to assess and verify GHG impacts and offsets of land use practices. However, the empirical models used in GHG calculators draw heavily on measurements from temperate, developed countries, which do not reflect the soils, climate or management of smallholder farming in the tropics. Use of GHG calculators to estimate emissions and stock changes in tropical, developing countries may misrepresent emissions because the models are forced to predict outside of their calibration conditions. We compared GHG fluxes and carbon (C) stock change estimates from two GHG calculators—the Cool Farm Tool and EX-Act—against measured GHG fluxes for a range of production conditions in tropical developing countries of America, Africa, and Asia. Our results showed that these tools overestimate GHG fluxes and C stock changes in smallholder agriculture. In over 25% of cases, the tools also incorrectly predicted whether emissions would increase or decrease with the adoption of a particular agricultural practice. These results spotlight the danger of relying on simple calculators for quantifying and verifying emissions and C offsets in these systems. While these tools use the best available empirical models, there is a strong need for additional data to calibrate GHG calculators in order to accurately evaluate the mitigation co-benefits of climate-smart agricultural practices in tropical, developing countries.

51. PERPHECLIM ACCAF Project - Perennial fruit crops and forest phenology evolution facing climatic changes

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Phenology is a bio-indicator of climate evolutions. Measurements of phenological stages on perennial species provide actually significant illustrations and assessments of the impact of climate change. Phenology is also one of the main key characteristics of the capacity of adaptation of perennial species, generating questions about their consequences on plant growth and development or on fruit quality.
Predicting phenology evolution and adaptative capacities of perennial species needs to override three main methodological limitations: 1) existing observations and associated databases are scattered and sometimes incomplete, rendering difficult the implementation of multi-site study of genotype-environment interaction analyses; 2) there are no common protocols to observe phenological stages; 3) access to generic phenological models platforms is still very limited.
In this context, the PERPHECLIM project, which is funded by the Adapting Agriculture and Forestry to Climate Change Meta-Program (ACCAF) from INRA, has the objective to develop the necessary infrastructure at INRA level (observatories, information system, modeling tools) to enable partners to study the phenology of various perennial species (grapevine, fruit trees and forest trees). Currently the PERPHECLIM project involves 27 research units in France.
The main activities currently developed are: defining protocols and observation forms to observe phenology for various species of interest for the project; organizing observation training; developing generic modeling solutions to simulate phenology; supporting the building of research projects at national and international level; developing environment/genotype observation networks for fruit trees species; developing an information system managing data and documentation concerning phenology.
Finally, PERPHECLIM aims to build strong collaborations with public (Observatoire des Saisons) and private sector partners (technical institutes) in order to allow a more direct transfer of knowledge.

52. Potential for biochar to mitigate N_2O emissions is minimal at the field scale and in upland cropping systems

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Soil amendment with biochar as a means to reduce agricultural N_2O emissions has received much recent attention. Significant work has been conducted to elucidate the effect of biochar on N_2O emissions in relation to changes in soil pH, soil hydrology, aeration and carbon (C) and nitrogen (N) cycling. Nevertheless, many questions remain regarding the consistency and duration of biochar-soil interactions across soil and biochar types, crops and climates, especially under field conditions. Here we present the results of a meta-analysis using only field studies; the data set includes a total of 47 observations from 15 studies and 17 field sites. Rice systems accounted for 53% of observations, followed by: wheat (15%), pasture/ryegrass (13%), wine grape (9%), and other (11%).

Our results show mean emission reductions between 17-19% following biochar amendment; while significant, this value is 65% lower than that of a recent meta-analysis which relied predominately on laboratory studies. Additionally we observed significant differences between cropping systems. The mean response ratio in rice systems was more than 2.5 times that of upland cropping systems; -26.3 to -33.9% versus -6.4 to -8.5%, respectively, with the latter not being significantly lower than zero, demonstrating a net null effect. The significant effect of crop type (rice versus upland) and the difference in magnitude of N_2O mitigation potential between laboratory and field experiments warrants caution when extrapolating results to broader contexts. These results have significant implications for the development of biochar amendment as a climate smart agricultural practice, to predict the regional and/or global impact via modeling of biochar amendments on global warming potential, carbon offsets, and life cycle assessments, and the needed policies associated with biochar amendment programs. Hence, it is imperative to collect good quality field data to better determine what and where biochar application makes sense.

53. Facilitating climate adaptation in irrigated agriculture with decision support systems: El Molino platform

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Climate change represents one of the most important challenges for irrigated agriculture. Increasing temperatures and reductions in precipitation experienced by Mediterranean and semi-arid areas around the world, not only impact crop growth and development, but also jeopardize the ability of water provision systems to meet agricultural water demands. The incorporation of adaptation measures, either incremental or transformational, requires a framework to identify the vulnerability of agricultural systems and evaluate their performance (residual impact of climate change). We present a decision support system that facilitates the ex-ante evaluation of adaptation measures for irrigated agriculture in Central Chile. We worked under the assumption that vulnerability is determined by several variables (climate, hydrology, irrigation system, agronomic practices, ecological services and socioeconomic factors). We built an online interactive model that allows several types of users to obtain individual information about likely climate change impacts and to explore adaptation options. The platform called El Molino (Water mill) has been designed to produce user specific reports based on uploaded information and using an integrated model that connects Climate Change projections (RCP scenarios from different GCM models), statistical downscaling (suitable for climate change and climate variability), a hydrological model that allow us to evaluate impacts on streamflows and distribute water to several agricultural nodes, and a crop simulation model that translates climate impacts into yield and evapotranspiration changes. For each system individual metrics to evaluate vulnerability and the impact of adaptation strategies have been developed. The platform can be used by farmers to directly evaluate impacts of climate change/variability on their individual farms and crops, as well as by water authorities to study the vulnerability of different areas (as users upload information, regional patterns tend to express themselves). Surveys campaigns were carried out to collect farmer information in two basins allowing us to examine the preliminary results of this project.

We thank the Chilean grant FONDEF D10i1051 and the National Commission of Irrigation for their support.

54. A model-based approach for adapting cropping systems to climate change

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The definition of cropping systems adapted to future climate conditions remains a challenge for two main reasons. First, cropping systems are characterized by a large number of components related to crop succession and cropping practices, and this complexity generates a large number of possible cropping systems that need to be evaluated. Second, cropping system performance cannot be measured by a single variable, but rather by a diversity of criteria related to crop production and environmental impacts. The objective of this study is to present a methodological framework for adapting cropping system characteristics to future climate conditions and for evaluating their agronomic and environmental performances according to 12 different criteria. Our approach is based on two major points: first, a hybrid model combining a biophysical model and a set of quantitative indicators; and second, a conceptual framework to modify cropping systems in a functional manner. The hybrid model is able to rank a large diversity of cropping systems under different climate change scenarios and to identify systems showing good performances for several of the considered criteria. We use a global sensitivity approach to evaluate the robustness of the generated cropping system ranking, and show that this ranking is sensitive to some assumptions made on the model parameter values.

Acknowledgement: The authors acknowledge the support of the French Agence Nationale de la Recherche (project ORACLE)

55. Tweaking the system: optimization of mitigation strategies in smallholder flooded rice systems

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Mid-season drainage in flooded rice is known to reduce CH_4 emissions, while effects on N_2O emissions are more variable. The use of complex organic fertilizers (manure, compost etc.) may result in highly variable greenhouse gas (GHG) emissions, depending on the C and N availability of the substrate and the timing of flooding/drainage. In a series of field (Cambodia and Vietnam) and greenhouse experiments, we investigated the effect of a variety of organic amendments and wetting/drainage cycles on yield and GHG emissions. Overall, our results showed that drainage periods had minimal impact on yields, while reducing overall GHG emission. Mineral N additions generally lowered yield-scaled GHG emissions, due to strong yield responses, while organic manures generally increased or had no effect on emissions at field scale. Methane emissions were strongly controlled by C availability in the substrate (on equal total C-input basis), increasing in the order: biochar<composts<animal manures<fresh material. Direct comparison of treatments with and without biochar showed variable results, in some cases increasing CH_4 emission, in other cases reducing it. Cambodian farmers expressed concerns over labor consumption and re-supply of water after drainage. In response to that, we tested if early-season drainage could replace mid-season drainage. With addition of labile carbon substrates (straw), duration of early season drainage was more important for reducing GHG emissions, than duration of mid-season drainage, and had the largest potential for total emission reduction. Nitrous oxide emissions generally increased with draining cycles, but did not lead to an overall increase in GHG emissions, as its contribution was balanced by lowered CH_4 emissions. In conclusion, drainage periods are even more important for mitigating emissions when including organic manures or residues in flooded rice, and early-season drainage should be further explored as a more safe and convenient option for smallholders.

56. Effect of coated and uncoated dietary nitrate on dairy cow health and dairy product quality

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Supplemental nitrate (NO_3) persistently lowers enteric methane production by ruminants, but effects on milk quality have received less attention. If additives to lower methane emissions will be used in practice it is important to assess possible effects on the quality of dairy products. Ten rumen fistulated Holstein-Friesian lactating dairy cows (31.1±7.3L milk/day) were supplied with incremental amounts of NO_3 (Bolifor CNF, Yara, Norway) either A) uncoated (n=6) or B) fat-coated (n=4). Cows were fed a total mixed ration in which NO_3 was increased from 0% DM to 2.5% DM by isonitrogenous replacement of urea. Length of the experiment was 31 days with NO_3 (% DM) at 0% (3d), 1% (3d), 1.5% (4d), 2% (8d), 2.5% (5d) and stepwise down to 0% (8d). Blood samples were collected 3 and 6 hours after feeding on each day dose was changed and analysed within 15min for methemoglobin (MetHb). Milk of 6 consecutive milkings was collected on days 1-3 (0% dose) and 21-23 (2.5% dose), pooled within treatment group and processed into pasteurized semi-skimmed milk, Gouda 48+ cheese and semi-skimmed yoghurt. Dairy products were tested for macro composition, NO_3, nitrite (NO_2), nitrosamines and evaluated by a trained sensory panel. No difference was observed between MetHb levels of cows fed A or B, where levels increased linearly with NO_3 dose to a maximum of 10.6% of Hb (treatment group average). NO_3 in fresh pooled milk increased from 0.2 mg/kg to a maximum of 6.7 mg/kg (A) and 3.7 mg/kg (B), whereas NO_2 was below limit of detection in all samples (<0.04 mg/kg). Nitrosamines were not detected in fresh milk or any dairy product. No sensory differences were detected in pasteurized milk or yoghurt from cows fed 0% or 2.5% NO_3. Effect of feeding A on cheese sensory properties cannot be confirmed nor excluded based on this experiment, whereas B did not exhibit an effect. More research is needed obtaining increased volumes of milk from cows supplied with NO_3 to evaluate sensory effects further.

57. Rainwater harvesting and conservation: climate smart sustainable techniques for homestead and cropland production

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Subsistence farmers occupy large areas in the semi-arid region of Southern Africa. Crop yields and rainwater productivity (RWP) are low due to low and erratic rainfall and high evaporative demand. Climate predictions indicate an increase in temperature for Southern Africa, which will increase unproductive water loss thereby reduce soil water availability, decrease productivity and aggravate food insecurity. Rural households have access to homestead gardens and arable cropland. The objective of this study was to increase crop yield and RWP by making use of appropriate sustainable climate smart: a) manual rainwater harvesting and conservation (RWH&C) techniques in homestead gardens and b) mechanical RWH&C techniques in croplands.

Crop production was demonstrated with on-station and on-farm experiments in homestead gardens and croplands in South Africa, Botswana and Zimbabwe over a number of seasons. In-field rainwater harvesting (IRWH) was compared to conventional tillage (CON) in homestead gardens. Cropland treatments included CON, IRWH, Daling plough, mechanized basins and minimum/no-till. Soil water content, evaporation from the soil surface (Es), runoff (R), carbon content, grain yield, RWP, gross margins were measured and calculated. The number of households and communities implemented the CST were also monitored.

Sustainable climate smart RWH&C techniques: a) reduce Es; b) stop R; c) conserve rainfall for longer periods; d) minimize the risk of crop failure linked to erratic and declining rainfall and increasing temperatures; e) increase RWP; f) increase food production; g) conserve carbon as compared to CON. More than 1400 households in rural communities have implemented IRWH to improve their household food security status. The IRWH technique is a sustainable technique that contributes to climate change adaptation through increased plant available water, buffering during dry spells, increased yields and better RWP enabling food production.

58. Pathways for Climate Smart Agriculture (CSA) in the drylands of Africa

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This paper summarizes lessons learned on CSA in collaborative programs between Norwegian University of Life Sciences and national research institutes in Mali, Sudan and Ethiopia. A series of on-station and on-farms field experiments were conducted on CSA methods. Crop establishment is a critical factor in crop production as seedlings are very exposed to drought, pests and diseases. A key is to find low cost methods for CSA. The most simple and low-cost way to intensify crop production in the drylands is priming of seeds in water for prior to sowing. Seed priming was found to increase yields in the range of 20-50% pearl millet, sorghum and groundnut. Microdosing in the order of 0.2 to 0.6 g fertilizer per pocket (NPK or DAP) combined with seed priming increased yield by 30 to 100 %. The speediness of the work is also a critical factor in crop establishment as there are few days per year when sowing is feasible. Use of a sowing machine allows sowing to be done about 10 times faster as compared to manual sowing and application of primed seeds and microdosing by the use of the sowing machine is more precise, furthermore improving crop establishment. Additional gains were achieved through application of compost as microdosing, mulching, seed coating with insecticide/fungicide and urea top dressing as microdosing. By combining all these methods, a yield increase, up to a tripling, has been achieved in sorghum, millet and groundnut. These methods combined improve water use efficiency through earlier crop establishment (seed priming), more developed root system (seed priming and microdosing), less evaporation (mulching) and earlier harvest (all methods combined). The cash demand for this type intensification is very low, while the value cost ratio is typically above 10 making this type of intensification attractive to poor farmers. As these methods can be introduced in a sequential manner, they can be considered as pathway for Climate Smart Agriculture.

Acknowledgement: Financing from Norwegian Ministry of Foreign Affairs and Dryland Coordination Group.

59. Climate-smart agriculture: panacea, propaganda or paradigm shift?

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Development agendas focused on climate-smart agriculture (CSA) assume that changing farming practices can simultaneously improve food security, adaptation and mitigation outcomes. So far, however, there has been a lack of comprehensive information to evaluate this conventional wisdom. Here we report results from an appraisal of CSA's scientific evidence base. We conducted a meta-analysis of the effects of 65 farm management practices (leguminous intercropped agroforestry, increased protein content of livestock diets, etc.) on 22 indicators consistent with CSA goals (yield, water use efficiency, carbon sequestration, etc.). Our search of peer-reviewed articles in Web of Science produced 144,567 candidate papers. We screened titles, abstracts and full-text against predetermined inclusion criteria, for example that the investigation took place in a tropical developing country and contains primary data on how both a CSA practice and non-CSA control affect a preselected CSA indicator. Mapping the location of the 6,000 studies that met our criteria shows geographic and topical clustering in relatively few locations and around relatively few measures of CSA, indicating potential for bias and highlighting gaps in the evidence for desired CSA objectives (*e.g.*, gender inclusiveness). Furthermore, outcomes vary widely among studies and locations and are far from clearly positive or negative, suggesting the 'climate-smartness' of practices needs to be considered for local conditions and objectives to be meaningful. Co-located, cross-outcome research tends to be sparse except for a few outcome-by-practice combinations. Thus, grand conclusions about synergies and trade-offs among CSA components may be unsupported. This meta-analysis provides a useful benchmark of CSA's scientific basis and can support the transition from hype to meaningful impact on the ground.

This work was principally funded by CCAFS with supplemental support provided by IFAD, CIFOR and FAO-MICCA.

60. Evaluating agricultural mitigation and scaling up climate-smart practices using the FAO EX-Ante Carbon-balance Tool

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The quantification of agricultural greenhouse gas (GHG) emissions is an important component of the Climate Smart Agriculture (CSA) agenda, and a key step in managing and ultimately reducing those emissions in a cost-effective manner. The scale and speed of climate change requires considerable investment in filling knowledge gaps and in research, for the development of time and cost-effective decision-support tools to prioritize both adaptation and mitigation actions, in addition to increasing productivity. The EX-Ante Carbon-balance Tool (EX-ACT) is a land-based accounting system for estimating and projecting changes in the carbon balance over time. The carbon-balance is defined as the net balance from all greenhouse gases (CO_2, CH_4 and N_2O) expressed in CO_2 equivalent that were emitted or sequestered due to the implementation of an action or project as compared to a business-as-usual scenario. EX-ACT can provide ex-ante (as well as ex-post) assessments covering crop intensification, agroforestry, silvopasture, livestock development, perennial agriculture, watershed management, forestry development, and land rehabilitation. It is interactive, user-friendly, and flexible in terms of requirements for coefficients and site-specific data. While EX-ACT is primarily used for project design, it is readily scalable to program, sector-wide, and policy analyses. EX-ACT analyses have been carried out in over 50 countries on climate-smart investment projects worth more than $5 billion dollars. EX-ACT has proven useful in estimating the GHG-balance of such investments and in scaling up climate-smart practices.

61. Characterization, stability, availability of nutrients and microbial effects of kiln produced biochars

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In recent years the importance of biochar application in soil has increased tremendously as pyrogenic carbon (C) may act as an important long-term C sink. Biochar was prepared from maize stover, pearl millet stalk, rice straw and wheat straw in a pyrolysis kiln at the temperature of 400 °C. The stability of biochar in soil was studied by CO_2 efflux for one year. The effect of biochar on available N, P, K and microbial properties was also studied in a separate experiment continued for 67 days. The wheat and rice biochar exhibited higher cation exchange capacity (CEC) than the other biochar materials, while the pH values of maize and pearl millet biochar were higher over rice and wheat biochar. The maize biochar was richer in C, N and P contents. The energy dispersive X-ray spectrometry (EDS) analysis showed that wheat and rice biochar was richer in K and Si, respectively. Total C content was highest in maize biochar (66%) followed by pearl millet biochar (64%), wheat biochar (64%) and rice biochar (60%). The Fourier-transform infrared spectroscopy (FTIR) analysis showed the presence of various functional groups in biochar. The maize biochar exhibited stronger structural surface functional groups including aromatic C=C stretching. Among the four different biochar used for CO_2 efflux study, the maize biochar was found to be most stable showing reduced C mineralization to protect the native soil organic C. Contrarily, rice biochar exhibited higher C mineralization. The maize biochar being most stable in soil showed highest C enrichment in soil. The maize biochar enhanced the available N and P in soil, while wheat biochar increased the available K content in soil. The rice biochar being relatively labile in soil fuelled the proliferation of microbial biomass, thereby enhancing the physiological efficiency of microbes measured in terms of dehydrogenase activity. Maize biochar with higher nutrient values, especially N and P and C stability, could be advocated for enhancing soil fertility and long-term C sequestration.

This work was supported by the National Initiative on Climate Resilient Agriculture (NICRA) Project of Indian Council of Agricultural Research.

62. Effect of pyrolysis temperatures on stability and priming effects of C3 and C4 biochars applied to two different soils

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Biochar (BC) is a recalcitrant soil amendment that is being used for long-term carbon sequestration while also enhancing soil fertility. In an effort to better understand the interaction of soil type and biochar type, Mollisol soil samples (Minnesota) and Ultisol soil samples (Georgia) were incubated with biochars prepared from C3 (rice hull and wheat residues) and C4 (maize stover and switch grass) crop residues at 400 °C and 600 °C and the stability of biochars was studied by CO_2 evolution measurements for 60 days. The C3 and C4 biochars were applied to the Ultisol and Mollisol samples which had a long term history of cropping with C4 and C3 crops, respectively. Overall the total and fixed C content of biochar increased, while the N content decreased with increase in pyrolysis temperature from 400 °C to 600 °C, thus increasing the C:N of the biochar. The volatile matter component of biochar decreased significantly at the higher pyrolysis temperature. In Mollisols, the wheat straw biochar prepared at 600 °C was more stable than the rice hull biochar. However, in Ultisols, rice straw biochar was more stable than the wheat straw biochar. Corn stover biochar prepared at 600 °C showed greater stability in both the Mollisols and Ultisols. The wheat straw biochar and corn stover biochar prepaped at 600 °C showed negative priming of soil native organic matter, had greater potential for long term carbon sequestration in soil. The δ13C signatures of the CO_2 evolved on the 2nd day matched δ13C signatures of biochar confirming the contribution of biochar. On days 9 and 20 the δ13C signatures matched that of control soil indicating very little or no contribution of biochar to CO_2 evolution. Corn biochar prepared at 600 °C could be useful for enhancing carbon storage in both Mollisol and Ultisol.

The first author is extremely thankful to the Fulbright Nehru Scholarship Commission in India and the Fulbright Scholarship Board, Washington DC for providing necessary fund in the form of Fulbright Nehru Senior Research Fellowship to carry out the research work.

63. Smallholders farm carbon footprint reduced by agroecological practices (Highlands & East Coast, Madagascar)

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Carbon footprint calculation is being more and more used to assess the contribution of activities to greenhouse gas emission. This work aims to determine the impact of farm activities and agricultural practices to farm carbon footprint. The carbon footprint is the carbon dioxide equivalent impact of the activities within each farm. Smallholder farms located on two different soil and climate areas of Madagascar have been selected: 12 in the Highlands and 8 on the East Coast. The farms located in the Highlands were characterized by intensification of annual cropping systems using agroecological practices such as intensive rice farming system, composting organic residues and intercropping of annual crop and trees. Farms from the East Coast use agroforestry systems (simple and multiple tree species) and the traditional twice-a-year rice cropping system. Farm resource flow maps were developed in order to represent all of the structures and characteristics of each farm. GHG source and sink compartments' inventory was performed and emission factors adapted to each zone were selected from the literature. A local/specific farm carbon footprint calculator was developed. Results showed that average farm carbon footprint amounted to 3.04 Mg CO_2eq ha^{-1} y^{-1} and 7.69 Mg CO_2eq ha^{-1} y^{-1} in the Highlands and in the East Coast respectively. The intensive rice farming system alternating wet and dry period improved the farm carbon footprint in the Highlands by reducing methane emission while the traditional twice-a-year rice cropping system is an important source of methane in the East Coast. Nevertheless, the contribution of agroforestry systems in the East Coast allowed a farm carbon footprint reduction of between 15 to 51%.

64. Climate Smart Agriculture imperative in Nepal: prospect and challenges

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Nepalese agriculture solely contributes 34% to the national GDP and is providing employment to 66%. Nepal ranks as a country highly vulnerable to adverse effect of climate change, already experiencing frequent notable incidents. Agriculture sector is hit hard by increasing climate variability, most of the arable land being rain-fed (65%). Therefore, climate smart agriculture (CSA) has become indispensable to provide climate justice, along with the necessary safeguarding of agrarian livelihood. NDRI in support of CCAFS conducted a pilot study in Rupandehi, Mid-Western foot hill district of Nepal, aiming to identify the appropriate climate change adaptation approach and necessary incorporation into the mainstreaming policy. Three components of the project included: (a) prioritization of adaptation options (mainly rice & wheat), (b) crop yield forecasting for weather risk management using CRAFT, and; (c) climate index based agro-advisories services using ICT. The study found that technologies such as direct seeded rice, zero tillage are the priority for investment. The software tool-CRAFT through simulation determined the projected yields ranging from <1%-11%. Forecasting crop-yields was useful for national government, policy makers and scientists to anticipate the impacts of climate variations on agriculture and to give support in decision-making for food security management planning. Piloting of ICT based agro-advisories services was found to be effective in delivering the services to farmers. Agro web-portal, mobile added value to farmers, which was evident from good responses and increasing trend of willingness to pay for climate services. 70% farmers responded that climate services were useful and 54% farmers used agro-advisories messages, augmenting their products. However, establishing the climate service systems in the high microclimatic variability of Nepal, the necessity of robust infrastructure and skilled human resources for forecasting, the integration of national agencies (Hydro-Met, Agriculture, and communications) are the challenges.

65. Big data from small farms: analysis of drivers of food security across farming systems in sub Saharan Africa

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The large diversity of agricultural and food systems in sub Saharan Africa (SSA) makes efficient targeting of climate smart agricultural (CSA) practices difficult. To better quantify which type of CSA practices work where and for whom, and what sustainable intensification can mean for smallholder farmers in terms of increasing their food security, we have collated cross-sectional household data of a wide range of farming systems in sub Saharan Africa (now more than 20000 farm households included). We use these data to perform individual household level analyses on key food security and profitability indicators and assess the positive effects of CSA practices and other proposed pathways of farming system improvement on these indicators in different regions. Additionally, we quantify the contribution of different on and off-farm activities to food security under different future scenarios of market and population density developments. Depending on the region, between 20 and 50% of the smallholder farmers will not reach food security with the currently projected yield increases and price changes. CSA practices can really make a difference in the food security status of about 20 to 40% of the smallholder farmers (*i.e.* passing from food insecure to food secure households), independent of the region. Similar percentages apply to sustainable intensification, indicating that current projections of the impact of sustainable intensification are over-estimated. Key limiting factors for achieving food security are small (and still decreasing) farm sizes and soil degradation, resulting in low productivity. The analysis shows the importance of combining household level data of a wide range of systems with simple calculation schemes to improve our current estimates of what agronomic based interventions can realistically achieve for smallholder farmers in sub Saharan Africa. This analysis also highlights the importance of structural constraints to increase productivity in small farms.

66. Participatory action research in climate-smart villages of Tanzania: fast track for new potato resilient varieties

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Lushoto is the most densely populated rural district in Tanzania. Situated in the Northern highlands where potatoes are traditionally grown, this district produces more potatoes than some neighboring countries. Most of the potatoes produced in Lushoto are local varieties among which Kidinya is the most dominant. Even though potato is a traditional crop, farmers can plant economically only once a year due to heat during the short rainy season. Moreover varieties that farmers grow cannot resist high Late Blight (LB) pressure during the long rainy season. This demand-driven study is an attempt to remediate this situation. The action research model applied is intensive, as it combines training-of-trainers (ToT) and participatory varietal selection experiments. The ToT comprises five training modules that span two growing seasons. The first three modules are designed by facilitators to cover important aspects of integrated crop management. The second round of two modules is participant-led as topics emerge from the first round. Twenty one participants representing farmers, extension services and NGOs attended the ToT. Moreover, one mother and five baby trials were conducted in Lushoto, Kwesine, Boheloi and Maringo using a CIP protocol which disaggregates preferences by gender. The experiment comprised six CIP advanced clones (300055.32, 388676.1, 390478.9, 398208.29, 397073.7 and 392797.22), three improved varieties (Asante, Obama and Shangii) and Kidinya as local check. Results showed very highly significant differences between genotypes for fresh tuber yield and their resistance/tolerance to LB. Clone 398208.29, Shangii, Asante and 388676.1 were the most preferred by farmers regardless of gender for their resistance to LB whereas Kidinya completely died before maturity. Clone 398208.29 produced on average 36.21 t/ha of fresh tubers across trials against 12.26 t/ha for Kidinya. In the end, participating farmers unanimously selected five genotypes for further evaluations: 398208.29, 392979.22, 388676.1, Shangii and Asante.

This study is being funded by CCAFS, CIP and the Government of Tanzania.

67. Prospects of climate smart agriculture (CSA) under low-input and rain-fed conditions in southern Africa

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Volatile climatic conditions, poor soil fertility and low resource endowments are major causes of poor crop productivity on smallholder farms in southern Africa. Despite these barriers, innovative pathways are needed to produce more food per unit area of land, while rebuilding soil fertility. The objective of this study was to use climatic as well as agronomic data from a long-term trial at Monze Farmer Training Centre in Zambia as a case study to illustrate the existence and impact of climate variability on maize productivity under conventional tillage and conservation agriculture (CA) in southern Africa with the aid of the Agricultural Production SIMulator (APSIM) model. Analysis of historical climatic data (1980-2010) showed that the 2001-2010 period had higher rainfall variability (CV = 13.6) compared with the previous decade (CV = 8.2), and the incidences of either too low or too high rainfall were also more frequent in the 2000s compared with 1980s. Both maximum and minimum temperatures increased by about 0.5 °C from 1980 to 2010. The effect of this variability was well simulated by the APSIM model which showed that in severe water limiting environments such as the devastating drought of 1991/1992, no cropping system could achieve any meaningful grain yield. However, in the 1989/1990 season the conventional tillage treatment recorded no grain yield whereas 0.2 t ha^{-1} were achieved with CA. However in the wettest season in 2003/2004, conventional tillage outyielded CA by about 0.3 t ha^{-1}. These results suggest that CA has potential to mitigate against moisture stress but may depress yields when moisture is abundant. Generally, the rainy seasons are starting late which reduces significantly the planting window thus the option of staggering planting dates to deal with climatic uncertainties may not be viable in the future. Thus, intercropping systems may play an important role in dealing with climate uncertainty.

68. Climate change, promising technologies and ex ante analysis of impacts on agriculture and food security to 2050

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Achieving and maintaining global food security is challenged by changes in population, income and climate, among other drivers. Assessing these challenges and possible solutions over the coming decades requires a rigorous multidisciplinary approach. The Global Futures and Strategic Foresight (GFSF) program, a CGIAR initiative led by the International Food Policy Research Institute (IFPRI) in collaboration with 11 other CGIAR research centers, is working to improve tools and conducting ex ante assessments of promising technologies, investments and policies under alternative global futures. New baseline projections from IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) set the stage with the latest outlook on long-term trends in food demand and agricultural production based on projected changes in population, income, technology and climate. New analysis from the GFSF program then links climate, water, crop and economic models to assess the impacts of promising new climate-smart technologies for maize, wheat, rice, potato, sorghum, groundnut and cassava on yields, area, production, trade and prices in 2050 at a variety of scales. Yield gains from adoption of the selected technologies vary by technology and region, but are found to be generally comparable in scale to (and thus able to offset) the adverse effects of climate change under a high-emissions pathway. They are nevertheless dominated over the projection period by the effects of growth in population, income and general productivity, highlighting the importance of linked assessment of biophysical and socioeconomic drivers to better understand climate impacts and responses.

This work was supported by funding from the Bill and Melinda Gates Foundation, the CGIAR Research Program on Policies, Institutions, and Markets, and the CGIAR Research Program on Climate Change, Agriculture and Food Security.

69. Strategies for developing climate resilient genotypes of rice and chickpea

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Physiological approaches are viable options for developing heat tolerant genotypes in rice and chickpea for future climate change scenario. Phenotyping of germplasm, wild species and cultivated varieties, on the basis of physiological traits have been used for developing stress tolerance in various crops. In rice, reproductive stage is considered most sensitive to high temperature stress. Reductions in grain yield occur due to lower spikelet fertility, pollen viability and poor anther dehiscence. We identified a novel source of heat stress tolerance on the basis of seedling survival, spikelet fertility, grain yield in rice (Nerica L-44), and it has been introgressed with cultivated varieties for developing high temperature tolerant population. Acclimation response of signaling molecules (Ca+2) and growth regulators (SA and BR) have been tested in contrasting rice genotypes for improving high temperature tolerance. Lower concentrations of salicylic acid (SA) and Ca^{+2}, while brassinosteroids (BR) at all concentration ameliorated the high temperature stress effects which were more pronounced in sensitive genotype (Pusa Sugandh-5) compared to tolerant one (Nerica L-44). Similarly, chickpea genotypes have been phenotyped for high temperature stress tolerance. In chickpea also, flowering stage showed more sensitivity to high temperature stress in terms of flower/pod abortion ratio. Few genotypes, on the basis of flower/pod abortion ratio, pod weight and grain weight, have been identified for breeding program. In another study, potential signaling role of Ca^{+2} was analyzed in chickpea under controlled and normal environments. Results suggest that 10 mM Ca^{+2} foliar application before the onset of flowering, can acclimatize the chickpea plants and improve their high temperature tolerance. The findings of above studies suggest that among various approaches being used for developing climate resilient crops, phenotyping and breeding of genotypes with improved stress tolerance can be considered as a feasible option.

70. Simulation of spot blotch in wheat as strategic decision support for adaptation practice in changing scenario

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Spot blotch (*Bipolaris sorokiniana*) in wheat is an emerging disease in warmer areas in South Asia. Spatial dynamics of disease risk was simulated throughout Indo-Gangetic plains using hourly weather data. Based on infection favourable thresholds (18-34°C and 15 h RH>90%) and hourly generation rate (y) model [y= (0.002*air temp –0.03) 1 – exp [0.151(air temp – 36)]] spot blotch risk signatures were generated through Geographical Information System. Simulation indicated eastern Gangetic plains are relatively more favorable for disease development than western plains. Ground truth survey indicated a clear gradient of higher severity in eastern plains to low severity in western plains and corresponded well to the simulated spatial dynamics. Temperature rise (0.5-0.8°C) in current situation appeared to increase disease favourable hours and generation rate further in eastern plains and brought western plains under infection risk zone. Simulation of spot blotch favourable conditions for a 1.5°C rise above the current temperature indicated a sharp increase in spot blotch favourable conditions in western plains and the region shown to be more sensitive to temperature rise than eastern plains. Therefore, strategic monitoring is a must, as severity of the disease is likely to increase further with increasing trend in minimum temperature. Based on the temperature-RH h surface response on spot blotch index (Y) [Y=((36 - air temp)/7)×((air temp -16)/13)2.6×(1-[(0.8114)](D-m)) where D= high RH h and m=minimum RH h], a monitoring system worked out as a particular combination of temperature-high RH h (Y accumulated to 1.2) triggered infection. As subsequent development of the disease was dependent on prevailing air temperature, close field monitoring for spot appearance may be initiated based on the occurrence of air temperature 18°C or above with 15 h high RH and decision to apply fungicidal spray may be advised when air temperature starts increasing above 20°C.

Support from project ‘National Initiative of Climate Resilient Agriculture’

71. To evaluate reforestation in farms: a tool for smallholders and the sustainability of their initiatives (EvaRefo)

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Despite consensus on the necessity to reforest agricultural landscapes for climate change mitigation and adaptation, the experiences of many small landholders in reforestation are tarnished by difficulties leading to disillusionment and abandonment of initiatives. After clarifying with stakeholders of reforestation efforts in Balalaica, a biological subcorredor in Costa Rica, it became clear that the sustainability of an initiative depends on clear objectives, and a series of corresponding factors and well-timed decisions. In response to these needs, we elaborated a simple evaluation tool, EvaRefo. On the basis of indicator development, EvaRefo accounts for the different dimensions of reforestation sustainability as perceived by small landholder reforestation initiatives (ecological, economic, social and cultural). It distinguishes the potential of a reforestation initiative (whether favorable conditions are gathered) and its performance (how well are the trees growing and fulfilling expectations). The tool makes the most of scientific and technical knowledge on reforestation conditions and processes, while remaining operationally simple so that small landholders can use it without specific investment nor high-level technical knowledge. The self-evaluation of initiatives facilitates learning and capacity-building directly from field experience. EvaRefo was applied to six types of reforestation initiatives, focusing on different primary objectives, to visualize the kinds of tradeoffs that are involved by focusing on one goal rather than another: timber production, water conservation, ecological conservation, rural and scientific tourism, agroforestry, and payments for environmental services. Consistently low scoring indicators corresponded to aspects of associative and technical capacities, self-sufficiency, and species suitability, revealing that the farmer involved in reforestation often finds himself isolated to successfully manage his reforestation initiative.

72. Backyard potted yam cultivation in Abuja, Nigeria

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This paper presents the various techniques involved in planting of yam using a potted vessel for Food Security. Potted rubber plant containers were bought and yam seedlings were introduced into the different potted rubber plant containers, soils were also introduced with the yam seedlings. Observations were made in the different growing characteristics: the aspect of crawling, sticking, controlling of the planted yam. The result is that the yam performs very well, needs enough sunlight, more soil is needed to be introduced for adequate performance. It can be recommended for household yam cultivation that lack enough land. The control of the temperature and the technology is very simple, cultivation practices are also easy and it reduces the stress of weeding. Pictures were taken and people were made to see the various principles involved, questions were asked to participants, group discussions were also held.

73. Meta-analysis of the effect of dietary nitrate on enteric methane emissions in ruminants

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Nitrate has been identified as a dietary additive to mitigate methane emissions in ruminant livestock. Nitrate can serve as an alternative hydrogen sink, with the stoichiometric potential to reduce 2.58g methane per 10g nitrate included in the diet. To identify the size of the mitigation a meta-analysis was performed. Seven peer reviewed papers and four conference abstracts were identified which reported effects of dietary nitrate on methane emission resulting in 15 comparisons. Within each experiment, control and nitrate treatments contained equal concentrations of crude protein and non-protein nitrogen and methane emissions were expressed per kg dry matter intake (DMI). Meta-analysis was performed in R statistical program using the 'metafor' package. Both log transformed ratio and mean difference were calculated as dependent variables and animal species (dairy and beef cattle and sheep) and nitrate dose were tested as moderators. Using the random model, nitrate decreased methane emissions by 20.1% (±2.37SE; P<0.001) or by 3.8 g (±0.41SE; P<0.001) per kg DMI. Both animal species (P<0.001) and dose (P<0.001) were significant moderators in the mixed model, but when both moderators were included only dose was significant. Using dose (x = g nitrate/kg feed DM) as the sole moderator, methane reduction by dietary nitrate could be expressed as y = e^ [-0.010 (±0.0847SE; P=0.911) -0.012x (±0.0042SE; P=0.003)] as fraction of the control in g/kg DMI or y = 0.1 (±0.93SE; P<0.128) -0.199x (±0.0460SE; P<0.001) expressed as g methane decreased per kg DMI. Nitrate inclusion in the diet causes a dose-dependent decrease in methane emissions where 10 g nitrate reduces methane emissions by 2.0 g per kg DMI, which is 77% of the stoichiometric potential. This relationship can be used to develop policies to mitigate greenhouse gas emissions at the animal and farm scale.

Research conducted as part of AnimalChange, a project funded by EC-FP7/2007-2013 under grant agreement no. 266018.

74. Climate smart strategies to strengthened coffee farmers adaptive capacity to climate change

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In the last 30 years Kenya's national coffee production decreased by about 70%. In some areas like Muranga County, the decline was up to fivefold and coffee is now replaced by food crops in lower altitudes due to erratic rainfall and increased temperature. Projected mean temperature increase between 3ºC and 4ºC may result in yield losses of 8 - 22 percent by 2050 unless climate smart adaptation practices are undertaken. Adaptation depends on farmers noticing climate change has indeed affected them and perceiving the need for, and benefits from new production strategies. However, there is marked difference in the way scientists and farmers perceive climate change and how it affects agriculture. Therefore, this study aims to: 1) explore how cropping systems are changing; 2) analyse how scientists and farmers respectively perceive climate change; 3) present farm-level adaptation strategies and how climate smart strategies strengthen adaptive capacity of farmers. The study is based on interview of 120 farmers and collection of meteorological data. The data were analyzed in four directions: (1) farmers' perceptions about climate change, (2) trends for temperature and rainfall over 30 years, (3) relations between farmers' perception and climate data, (4) identification of adaptation strategies and adaptive capacity based on livelihood adaptation frameworks. The results revealed 1) 91 percent of the farmers perceived climate has changed, observing extended warmer seasons, changes in onset and cessation of rainfall which is indeed supported by meteorological data. 2) Only 54 percent of farmers are responding to the perceived changes, introducing climate smart practices such as varietal change, intercropping, irrigation and crop-livestock mixed farming. 3) Access to finance, human capacity building and information on weather are vital to strengthen farmers' adaptive capacity. We recommend further researches on future suitable places for coffee, with business as usual and climate smart practices to predict future winners and losers.

75. Linking agricultural adaptation strategies and food security: evidence from West Africa

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With the frequency of extreme weather events predicted to increase during the next decades in Sub-Saharan Africa, strategies rendering smallholder farmers less vulnerable to climate variability and seasonality must be identified and implemented. In this study, we explored the linkages between selected agricultural adaptation strategies (crop diversity, soil and water conservation, trees on farm, small ruminants, improved crop varieties, fertilizers), food security, and land productivity in three agroecological contrasting sites in West Africa. The proportion of food secure households per site was 48%, 18% and 55% in Kaffrine (Senegal), Lawra (Ghana) and the Yatenga (Burkina Faso), with land area per capita and land productivity explaining most variation across the sites. Based on land size and market orientation, four household types were distinguished (subsistence, diversified, extensive, intensified), with contrasting levels of food security and of practice of agricultural adaptation strategies. Income increased steadily with land size, whereas both income and land productivity increased as households were more market oriented. The adoption of adaptation strategies was widespread (greater than 60%), although the intensity at which they are practiced varied across household types. Adaptation strategies improved the food security status of some household types, but not all. Some strategies had a significant impact on land productivity, others reduced vulnerability due to a more stable cash flow all year long. Our results show that there are no one-size-fits-all solutions, and that for different farm types different adaptation strategies may be 'climate-smart'. The typology developed in this study gives a good entry point to analyse which practices should be targeted to which type of smallholder farmers, and quantifies the effect of adaptation options on household food security. This is an essential step to effectively scale out practices to reduce vulnerability.

76. Quantifying greenhouse gas emissions and carbon storage at the local scale in the U.S.

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When considering a management change, land managers require tools that will enable them to quickly and easily assess environmental benefits and environmental market opportunities. USDA enlisted the help of nearly 100 scientists to develop a technical report that provides guidance on best methods for estimating GHG fluxes at the local farm, ranch or forest scale. Four rounds of review by federal and academic experts were conducted to ensure validity and transparency of the contents. The report is an important step toward providing land managers with standardized and vetted GHG assessment tools.
The objective was to create a standard set of GHG estimation methods for USDA, providing tools that will help landowners estimate the GHG impacts of their management decisions. The methods presented in the report address GHG emissions and carbon sequestration for the entire farm, ranch or forest operation. The methods also establish the scientific basis for farm-scale estimation of the GHG impacts of land management decisions. A web-based tool is being developed following the guidance of the methods report that will demonstrate transparency, accuracy, completeness and ease of use. This effort assists landowners, NGOs, and other USDA stakeholders in assessing increases and decreases in GHG emissions and carbon sequestration associated with changes in land management, and aids USDA in assessing the GHG performance of current and future conservation programs and practices. The report authors noted many significant areas where research and/or available data are lacking. Filling these research and data gaps will further improve the accuracy and reliability of the methods.
This presentation highlights the methods and USDA efforts to implement these methods into user-friendly management tools. Also presented are challenges to be overcome and several key research and data gaps to be addressed to allow for more complete and accurate local-scale GHG inventory.

77. A systemic approach to evaluate shea parklands as possible smart agriculture to be intensified in Sudanese Africa

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We have set up a project on the « Roles of shea parklands in Reduction of vulnerability of AgrosysteMs and SociEties in Sub-Saharian Africa » (RAMSES) that has been submitted to several potential funders. This project ambitions to evaluate possible regeneration, extension and ecological intensification of shea production in Sudanese Africa, which is the only area supplying the whole world with shea nuts and butter. By this agroforestry practice, sub-Saharan societies seem to respond spontaneously to the MEA, diversifying their production while minimizing environmental degradation and deforestation impacts linked to extension of the cultivated areas. However, ecosystem services provided by shea trees are neither known nor quantified. Interactions between shea parklands and their associated socioeconomic systems is also currently in tension between the increasing demand at the international level and local degradations of shea stands with increasingly limited regeneration. This results in a worrying decrease in shea production capacity while enhancing competition between farmers, between genders (shea producers are women; trees and plots belong to men), or between private buyers on which the project propose a diagnosis. The project is based on multi-disciplinary investigations in two countries that are representative of the diversity of biophysical and socio-economic situations of the shea parklands, Benin and Burkina Faso. It ambitions to provide 1) a classification, with a geographic mapping support, of ecological combined to socio-economic conditions in which parklands are still viable from a past half-century diachronic and spatial analysis of their trajectory drivers; 2) under conditions where viability is proven, an assessment of increasing tree density impacts (i) on ecosystem services (ii) on the farms' income, by using quantification of the processes underlying services provided by trees, and a bio-economic model to simulate different tree densities.

78. Participatory methodology of agricultural extension to Climate Smart Agriculture development: a case in Brazil

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Agricultural extension has a relevant role in Climate Smart Agriculture. However, 'classical' approaches of agricultural extension, based on the transfer of scientific knowledge, are not able to respond to climate challenges. Participatory methods of agricultural extension are necessary. The objective of this study is to analyze the methodology used in "Experimentation in Agroforestry and Social Participation" project, developed in the city of Joanópolis, Brazil, between 2005 and 2010. The research was based on participant observation of the project's phases: a) Reality recognition; b) Training processes; c) Definition of farmers experimenters' group; d) Planning and implementation of experimental practices. The main results on each of these steps were: a) Reality recognition provided a framework for farmers' engagement and for setting appropriate targets; b) Training processes allowed both technical experts to present their scientific views and farmers to recover and put their knowledge in the discussion arena; c) The farmers experimenters' group was comprised of 12 farmers, all of whom had leadership characteristics. It is suggested that the engagement of leaders may favor the extension of the outcome in the medium/long term; d) The planning of experiments considered the farm as a whole in order to discuss the issues in an integrated manner. This approach favored the involvement of farmers who historically handle their farms in an integrated way. The experimental practices were based on agroecological principles, such as diversification, use of organic inputs, soil cover, among others. The experimental practices were used as demonstration for other farmers. Dialogue and reflection from the experimental practices produced new and agroecological ways of doing agriculture. This project presents learnings and directions to a participatory construction of knowledge in order to contribute to Climate Smart Agriculture.

L2.2 Facing climatic variability and extremes

79. Consequences of high temperatures and drought on peach fruit production strongly depend on their period of occurrence

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In the context of climate change and increasing water scarcity, the adaptations of orchard management and irrigation strategy in order to maintain crop yield are needed. Maintaining crop quality is another major objective that has seldom been taken into account despite the consumer's demand for better tasting fruits. Experiments have been carried out to evaluate the impact of climate change on fruit production and quality. Irrigation deficits or increased temperatures have been applied during different stages of the fruit development of *Prunus persica* L. Batch to determine the key periods and the key processes sensitive to extreme climate events.

During the initial stages of fruit development, both water limitation and increased temperature strongly promoted fruit abortion. Water limitation also strongly reduced fruit size at harvest and consequently fruit commercial value. On the other hand, elevated temperature led to an acceleration of the vegetative growth that could trigger a competition between fruit and leaf for assimilate supply, thus increasing fruit abortion. Water limitation during cell division also modified fruit cuticular properties and induced an increase in fruit transpiration.

Water limitation during peach stone formation did not affect the diameter and the flesh composition of the ripe fruit. When water limitation was applied later, *i.e.* during fruit expansion and ripening, fruit growth was delayed but the sugar content of the fruit flesh was improved (metabolic composition estimated using robotized biochemical phenotyping and metabolomic profiling).

These results underline that the initial stages of fruit development are critical. They are very sensitive to water deficit and increased temperature, which impact final fruit yield and composition.

Considering these responses, a cooperative work must be engaged between ecophysiologists and geneticists to design new peach genotypes better adapted to Climate Change.

80. Reducing uncertainty in prediction of wheat performance under climate change

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Projections of climate change impacts on crop performances are inherently uncertain. However, multimodel uncertainty analysis of crop responses is rare because systematic and objective comparisons among process-based crop simulation models are difficult. Here we report on the Agricultural Model Intercomparison and Improvement Project ensemble of 30 wheat models tested using both crop and climate observed data in diverse environments, including infra-red heating field experiments, for their accuracy in simulating multiple crop growth, N economy and yield variables. The relative error averaged over models in reproducing observations was 24-38% for the different end-of-season variables. Clusters of wheat models organized by their correlations with temperature, precipitation, and solar radiation revealed common characteristics of climatic responses; however, models are rarely in the same cluster when comparing across sites. We also found that the amount of information used for calibration has only a minor effect on model ensemble climatic responses, but can be large for any single model. When simulating impacts assuming a mid-century A2 emissions scenario for climate projections from 16 downscaled general circulation models and 26 wheat models, a greater proportion of the uncertainty in climate change impact projections was due to variations among wheat models rather than to variations among climate models. Uncertainties in simulated impacts increased with atmospheric [CO_2] and associated warming. Extrapolating the model ensemble temperature response (at current atmospheric [CO_2]) indicated that warming is already reducing yields at a majority of wheat-growing locations. Finally, only a very weak relationship was found between the models' sensitivities to interannual temperature variability and their response to long-term warming, suggesting that additional processes differentiate climate change impacts from observed climate variability analogs. In conclusion, uncertainties in prediction of climate change impacts on crop performance can be reduced by improving temperature and CO_2 relationships in models and are better quantified through use of impact ensembles.

81. Managing climate induced risks and adaptation in the agriculture sector; a case of Punjab province Pakistan

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Though climate change is a global phenomenon, developing countries are more exposed to climate change due to their low adaptive capacity and greater dependence on climate sensitive agriculture. Pakistan is one of the countries at high risk due to climate change vulnerabilities. During the last decade, Pakistan has experienced severe floods, droughts and extreme weather events. Based on household surveys of 450 farmers from three agroecological zones of Punjab province, this study tries to investigate the farm-level exposure to various climate induced events and perceived risks or effects of climate change by the farm households along with farm-level remedies to these perceived risks. According to the results of the study, extreme temperature, increase in animal diseases, insect attacks, extreme low temperature, and severe pest attacks were the main events perceived by farmers. In terms of main effects of climate-induced events, farmer perceived uncertainty or reduction in crop yields due to changes in climate followed by water shortage, increased risks due to pest and crop diseases as major effects of climate change. In response to long-term changes in climate, farm households adopted various adaptation measures such as changing crop varieties and types, planting trees and changing fertilizer etc. The study also found a weak link between public or private organizations in adapting agriculture to climate changes. The study establishes a conceptual framework based on collected farm level information for the better understanding of the process and potential role of different stakeholders in adapting agriculture sector to climate change in Pakistan. The study suggests designing effective integrated policy for climate change adaption in agriculture sector through joint collaboration of various stakeholders working for farmers' welfare in Pakistan. In addition, the study also proposes the need of research at grassroots level in designing these policies.

82. Veille Agro Climatique (VAC): a real time monitoring tool for agroclimatic conditions

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Since the heat wave of the summer 2003, INRA has developed a monitoring tool of climate impact on agriculture in France. This operational climatic service, called VAC (Veille-Agro-Climatique), is based on data of meteorological INRA network and STICS crop model. It offers in real time two types of information. In a first case, agroclimatic indices are calculated each day in 18 locations (INRA agroclimatic stations) to characterize thermic and hydric conditions of cultures (as sum of temperature, of rainfall, water balance…). Graphics show daily evolution and are compared with the previous years (the climatic series begin around 1970). In the second part, STICS crop model is used to simulate 5 crops (monocultures of wheat, sunflower, maize, pea and rape). The approach adopted is based on a limited number of sites (10), representative of the main climatic regions, but also of soils and cultural practices. The goal is to identify climate impact on agriculture and for that, climate is the only factor of variation. Outputs concern production ("climatic yields") and phenological (length of stages) information. Results are offered every 10 days of the current year and a statistical prediction, using climatic data of the previous years from the date of the present day to the end of the year, allows to estimate a potential yield. All results are plotted and integrated in a web site (w3.avignon.inra.fr/veille_agroclimatique). A new version is on project for 2015-1016, to take into account the spatial dimension (Safran reanalysis, 8x8 km pixel) and seasonal prediction from Meteo-France.

83. Modelling of extreme climate events for South Africa using historical data and general circulation models

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Climate extremes associated with temperature and precipitation can have severe impacts on society, in particular in agriculture, water resource management and energy consumption. These are some of the problems currently South Africa is facing. In this study we used two methods to study extreme weather and climate events, namely statistical modelling using Extreme Value Theory (EVT) and modelling using General Circulation Models (GCMs).

The comparison between the results obtained by the extreme value theory and those obtained by the statistical downscaling technique shows that summer maximum temperatures at Mexicali City are similar throughout this century. For extreme rainfall events however the statistical downscaling technique yields different results.

84. Beyond incremental change: transformation to climate-smart agriculture in response to changing extremes

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Adopting climate-smart agriculture usually involves systems change. Experience shows this often is limited to incremental change to existing systems: and does not include more systemic or transformational options. We argue that transformational adaptation (TA) is an important option to consider in a comprehensive adaptation portfolio for climate-smart agriculture especially in response to increasing variability and risk from extremes. However, TA continues to be generally positioned as an option of last resort: as forced, negative, reactive, and a matter for the distant future. We suggest that to support decision-makers in considering TA as a serious proposition in the present, key principles on this scale of change would assist. To derive these principles we have moved beyond theory to empirical evidence. We use 218 interviews with decision-makers and other stakeholders across multiple Australian agricultural industries addressing both adaptation and mitigation to propose four broad principles. Firstly, TA cannot be achieved in isolation even where the immediate decision can be made unilaterally; it requires dependency on others which necessitates processes such as participatory engagement that embrace contested values, promote agency, and provide adaptive governance. Secondly, networks can play a key role in driving transformation, as can an understanding and use of climate risk management tools, access to technical and management options, substantial managerial capacity, and institutional arrangements that support or at least do not impede TA. Thirdly, the uncertain, long-term and far-reaching nature of TA means that continuous monitoring and evaluation of impacts and conditions is crucial - challenging for the many agribusinesses that do not have adequate capacity. Finally, the capacity to successfully undertake TA requires not only the resources and enabling conditions required for general adaptation but specific personal characteristics such as planning ability, comfort with uncertainty, leadership, belief in anthropogenic climate change, and willingness to change.

85. Strengthening the capacity of local extension services to face agroclimatic risks for production systems

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Crop and livestock losses due to extreme climatic events (droughts and floodings) during the last decade in Colombia have generated a response by the Colombian National Agricultural Research Institution, Corpoica, which developed a strategy to strengthen the capacity of local extension services to manage agroclimatic risks and recommend adaptation responses for production systems in 54 municipalities of 18 departments of Colombia. The strategy consisted in the analysis of climate variability (ENSO events during the period 1981-2010) and their temporal and spatial expression in the territory as floodings, droughts as the basis for evaluating potential risks at regional and local scales. Regional patterns were identified under three climate scenarios: Niño, Niña and Neutral. For each scenario, the following were calculated: drought, flooding and suitable soil water probabilities (Palmer, 1965), for each cropping season. Cropping dates and management practices were obtained through local workshops with the participation of local stakeholders. Finally, productive niches of lower agroclimatic risks were identified combining climate risks, land use capability (FAO, 1976) and water demands for selected crops under each climate scenario. Agroclimatological zonification maps produced combined expert and local knowledge on land and crop susceptibility to climate hazards. This information is being used to develop an early warning agroclimatic system to support adaptation responses according to climate forecasts and predictions.

Acknowledgements: Fondo Adaptación for financial support to carry out project activities

86. Grassland manipulation experiments across climatic zones

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Climate change is expected to have contrasting effects on grasslands: i) an initially positive effect of elevated atmospheric CO_2 which may decline through time (*i.e.* acclimation), ii) a site-dependent effect of warming, iii) a negative (or nil) impact of droughts and increased rainfall variability. Moreover, climate variables may have interacting effects, which adds to the difficulty of predicting climate change impacts on grasslands. Furthermore, the frequency and intensity of weather events and the biodiversity, structure and dynamics of the plant and soil communities may modify responses to climate change. Such interactions can only be studied by manipulating climatic drivers across a network of grassland sites including temperate, sub-tropical and tropical sites. Within the EC FP7 project AnimalChange, we aim at comparing grassland responses to manipulations of rainfall, atmospheric CO_2 and air temperature in contrasted climates in Europe (France, Hungary, Ireland, Switzerland), South America (Brazil) and Africa (Senegal, South Africa). Five out of seven sites have manipulated rainfall in field conditions, one site has manipulated atmospheric CO_2, and one site has manipulated atmospheric CO_2 in combination with temperature and rainfall. Preliminary results emphasize important changes in grassland production and forage quality induced by changes in precipitation but do not evidence an increased sensitivity of mesic compared to dry grasslands. Elevated CO_2 enhanced the recovery of a mesic grassland following a summer drought and heat event.

87. Building a global framework for banana resilience and adaptation under increased weather variability and uncertainty

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Bananas ensure income, food and dietary diversity to millions of tropical and subtropical households. Although bananas prefer warm, moist conditions for year round production, their cultivation has been adapted to suboptimum climates, including the monsoon tropics, the wet and dry subtropics and tropical highlands. We hypothesize based on this diversity of climates and production systems that banana will continue to prosper with the increased temperatures projected under current emissions scenarios. We also hypothesize that grower practices in response to weather variability and extremes across the globe can be harnessed to strengthen the resilience of the banana sector for climate change adaptation. Two studies served to test this framework. A model of annual leaf emission based on temperature and temperature/water was developed to map shifts in banana suitability globally with climate projections for 2030, 2050 and 2070. To examine response to weather variability, historical weather variability for Ecuador was reconstructed using CRU data and compared with weather station records. Grower focal groups provided insight into management flexibility. Finally global maps were used to identify zones with similar conditions to the main Ecuadorian banana production areas. Results confirmed our hypotheses. Globally few areas will be lost for banana production due to excessive temperatures, while many subtropical and tropical highland areas will become more suitable. In Ecuador growers identified four weather disruptions to productivity and profitability: cool temperatures, extended droughts, flooding and excess rainfall. Increasing weather volatility may be a greater threat than average temperature increases. In partnership with four regional banana networks we are developing an on-line global survey to inventory grower practices to address 20 common weather events and a socio-ecological resilience framework to plug banana-specific analysis into national adaptation planning.

88. Gauging the effects of extreme climate events on European crop yields

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Climate is a key determinant of crop production levels and interannual variability. Of particular interest are extreme climate events because they pose a growing threat to the stability of food supplies. In the European Union, the JRC-MARS Crop Yield Forecasting System delivers monthly yield projections to the European Commission's Directorate General Agriculture and Rural Development (DG AGRI). However, it has been acknowledged that such systems tend to underperform under extreme conditions. A better understanding of the impacts of extreme climate events on crop production is a prerequisite to the development of more effective early warning systems and adaptation strategies.
In this contribution we thus address the following questions[1]: (i) How can we build robust indicators of the potential impacts of climate extremes on crop yields? (ii) Can we improve the reliability of yield projections by applying statistical relationships between these indicators and yield extremes?
To answer the first question, we present a series of climate indicators of increasing complexity targeting wheat and maize growing seasons, and discuss results of their application to detect extreme climate conditions at the regional and national scales.
Then, we compare the prediction accuracy of a set of indicators at sub-national scales, and we rank them according to their ability to predict extreme yield losses. We show that simple climate variables are able to estimate the probability of high yield loss up to one month ahead of harvest with a good accuracy. Importantly, we also show that there is no straightforward relation between the complexity of a given indicator and its ability to accurately predict yield extremes.

[1]This work is a contribution to the EU-FP7 project MODEXTREME, whose overarching goal is to improving the capability of biophysical models to simulate vegetation responses to climatic variability and extremes.

89. Development of district contingency plans as a coping strategy to face climate variability and extremes in agriculture

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The southwest monsoon accounts for nearly 75% of the rainfall received during a short period of four months (June to September) in India. Onset and progress of monsoon across the country influences production of food grains and the agricultural economy. Rainfed agriculture in India constitutes 58% of the net cultivated area and accounts for 40% of the country's food production. Despite a high probability of rainfall being erratic, yearly agricultural planning by the state departments is geared heavily towards driving growth assuming a normal rainfall season. The occurrence of the widespread drought in 352 districts across the country during 2009 prompted the central government to recommend preparation of district-level contingency plans for climate risks in agriculture. A standard template was designed and contingency plans prepared for drought and other extreme weather events by the ICAR-Central Research Institute for Dryland Agriculture in collaboration with multi-disciplinary teams of scientists at 45 State Agricultural Universities. So far 580 district plans have been made available for implementation to the State governments. Suggested contingency measures for delay in monsoon onset include adoption of short duration and drought tolerant cultivars to suit the shortened season; substitution with low water requiring crops; adoption of crop combinations instead of sole cropping; suitable grain or fodder crop and cultivar choices for advancing rabi planting in case kharif crop failure due to severe drought. Experience of the droughts in 2012 and 2014 indicated that strengthening of seed supply chain is critical for implementation of contingency plans. Pilot implementation in farmers' fields on real time basis is underway in all the drought prone states by 23 dryland network research centres and Krishi Vigyan Kendras in 100 vulnerable districts under the national initiative on climate resilient agriculture project. Feedback from these demonstrations is driving policy changes for effective operational use of the contingency plans

90. Why role of local institution is crucial in Climate Smart Agriculture? Some evidence from rice-wheat system of Nepal

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Agriculture, which is at the fore-front of climate change impact, is going to enhance the challenge of feeding growing population with declining global food production. However climate change impact in agriculture is not uniform to all regions. Developing countries like Nepal suffers more. This is because understanding progressive change in temperature and precipitation is not sufficient. In context of Nepal, micro-climatic variation is even higher and requires instant understanding and response to protect farmers from heavy economic loss. Hence this paper explores some of the cases of Nepal to understand importance of local institutions for climate smart agriculture.

A mixed method approach was used for the study. Quantitative data were collected by means of household questionnaire survey from four district of terai region. The qualitative data were obtained by key informant interview, focus group discussion, semi-structured household interviews, historical timeline and observations.

This paper suggests the importance of local institutions to link scientific knowledge with farmer's perception which helps to measure the down-scale impact of climate change. Research findings suggest that the role of local institutions is not sufficient for adopting climate smart agriculture practices. Farmers need authentic climate information and alertness to adapt local consequences of climate change and adopt climate smart agriculture.

91. Introducing a legume cover crop in rubber plantations is not necessarily an option for their sustainability in dry areas

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Rubber plantations (Hevea brasiliensis) are expanding in areas with low soil fertility, long dry seasons, and high risks of soil erosion in rainy seasons. The introduction of a N_2 fixing legume cover crop in the interrows of the tree plantation might reduce runoff, soil erosion and increase the availability of nutrients and the growth of young trees. This study aimed at quantifying over a four year period (2007-2010), the impacts of a legume cover crop (Pueraria phaseoloides) to N nutrition, water status, and growth of young rubber trees planted along a toposequence with contrasted soil depths in north-east of Thailand.
The biomass production and N released by the legume reached 8 $Mg.ha^{-1}y^{-1}$ and 240 kg N. $ha^{-1}y^{-1}$ respectively. The N_2 fixation rates of the legume averaged 81% and N transfer from the legume to the rubber tree was also high; an average of 58% of tree leaf N was derived from atmosphere. Both variables were not significantly different along the toposequence. At the bottom of the toposequence, the combined improvement of nitrogen and water status of the trees in the rubber tree/cover crop system resulted in doubling the tree girth at seven-year age. At that position, the root profiles and soil water dynamic suggested that the cover crop allowed the rubber tree roots to tap water from deep soil layers during severe drought periods. Conversely, at the top of the toposequence where water was not available at depth, the legume had negative impacts on tree ability to survive intense drought.
It is concluded that improving N nutrition of young rubber trees in marginal area could affect their resilience to drought. In a context of climate change, the questions of where and how the best trade-off between N and water nutrition of crops could be achieved would concern more and more areas.

92. Sustainability of the Koga irrigation scheme: adaptive water management to deal with climate variability and change

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Background and Objective: The agricultural sector is very sensitive to climate change. For Ethiopia, a country highly reliant on the agricultural sector and with a low adaptive capacity (due to the existing low levels of development) the impact of climate change has much more implication. This is why water development projects that aim to alleviate climate change impact by converting the rainfed agriculture to an irrigated one are being implemented around the Lake Tana basin. This is considered as a low regret adaptation option in literature. However, we believe that ensuring the sustainability of these projects under an uncertain climate will require further work. Therefore this study was conducted with the aim of finding suitable adaptation options for possible water shortage problems at the Koga irrigation schemes, the only medium scale irrigation scheme which is currently operational in Lake Tana region.

Methods: Data were gathered through key informant interviews with 15 different stakeholders of the Koga irrigation schemes (project manager, canal operators, agronomist, water users representatives and farmers) and a questionnaire survey given to 90 Koga irrigation water beneficiary farmers. The data were analyzed using a content analysis.

Results: By the end of this study we were able to recognize the benefits and existing challenges of the irrigation scheme. The different stakeholders' perception of climate change was also evaluated. There seems to be a common agreement on temperature rise and an increase of rainfall amount. From the analysis of the different questionnaires and interviews we were able to screen out 14 adaptations options that will permit to tackle current water allocation problems and future climate induced problems. The identified adaptation options can be classified into these 4 categories: using supplementary source of water, increasing water use efficiency, water saving technologies, avoiding sedimentation of the reservoir.

Conclusion: The Koga irrigation scheme is a well-functioning irrigation that is currently benefiting 10,356 households. However, in order to ensure the sustainability of the scheme under an uncertain climate, measures that will avoid water loss or that will improve the farmer's adaptation capacity to water shortage need to be implemented based on evidence-based study.

93. Pearl millet yields and climate evolution across the last 20 years in central Senegal. A yield gap study

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The study focuses on the evolution of yield of pearl millet in central Senegal between the early 1990s (P1) and present time (P2). Mean air temperature and total annual rainfall both increased between P1 and P2. To avoid confounding effects due to these differences in climate with other possible causes, yields measured in farmers' fields (Ya) in the two periods were compared with estimates of potential (Yp) and water-limited (Yw) yields obtained using a crop model. Ya were extremely variable across fields whatever the period (100 to 1937 $Kg.ha^{-1}$) and much lower than simulated Yw (1343 to 3251 $Kg.ha^{-1}$). Resulting from interactions between changes in sowing dates, the photoperiod sensitive nature of the cultivars used, and the distribution of changes in temperature across the rainy season (increasing in June and July, and decreasing in August and September), cycle durations were slightly but significantly increased between P1 and P2, whereas solar radiation decreased concomitantly with the increase in rainfall (from 377 to 614 mm). This provoked a decrease in Yp (3076±14 $Kg.ha^{-1}$ in P1 against 2843±37 $Kg.ha^{-1}$ in P2), whereas Yw increased (1959±92 $Kg.ha^{-1}$ in P1 against 2571±72 $Kg.ha^{-1}$ in P2). With the change in Ya, passing from 835±105 $Kg.ha^{-1}$ for P1 to 525±43 $Kg.ha^{-1}$ for P2, the resulting yield gap Yw-Ya significantly increased (1124±140 $Kg.ha^{-1}$ in P1 against 2045±77 $Kg.ha^{-1}$ in P2). Field management did not significantly change between P1 and P2. It is concluded that the low yields and their stability across climate variations were due to the non-intensive nature of the cropping system. The impact of climate change on agricultural systems of the region should be studied accounting for complex interactions between rainfall, temperature, and radiation and for possible changes in cropping systems in response to changes in the economic environment of farms, that would likely change the crop's sensitivity to climate variables.

94. Effective adaptation strategies and risk reduction to increased climatic variability among coffee farmers in Mesoamerica

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Mesoamerica is a highly vulnerable region to climate change due to its geographical location and its topography. High levels of poverty and inequality augment its vulnerability. In the past decade, the area was hit by a series of extreme weather events and the impact on the agricultural sector increased the already high level of food insecurity and risk of famine among poor families who rely on subsistence agriculture.

Coffee is one of the important cash crops in the region seriously affected no only by these extreme events, but also by economic crisis resulting from a high price volatility and also by the impact of various pests, most notably coffee rust in the last two years.

Our objective was to study the strategies followed by small coffee growers in the face of a multi-stressor environment of global nature, including an increased climatic variability. The study was conducted in Mexico, Guatemala, Honduras and Costa Rica where we followed the adaptation strategies and the barriers to adaptation among farmers for the last twelve years.

We observed a change in perception about the importance of climate change as a stressor. In our first round of interviews in 2003, only 25% of respondents included climate events as a major concern. A second interview in 2007, after a series of tropical storms hit the area, reported that more than 50% of respondents cited extreme weather events as their greatest concern.

Most farmers interviewed perceive that there is a change in the climate manifested by warmer days and increased variability in the rainfall, particularly in the start and end of the rainy season. They also report an increase in pest incidence and aggressiveness of infestation. The barriers identified by farmers limiting their adaptation capacity are: limited access to financial resources and to information, particularly in terms of new agricultural practices and crops; also, difficulty in remaining organized, particularly in times of low external pressures.

95. Impact of climate change on crop production in southern Mali and the potential of adaptation strategies

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Climate variability and change are affecting rural livelihoods in Mali today and present a growing challenge in the region, as in many other parts of the African continent. We used a database of long-term (from 1965 to 2005) weather records and crop yields of a field experiment conducted from 1965 to 1993 at the N'Tarla in southern Mali to quantify possible historical changes of climate and their impact on yields of cotton, sorghum, and groundnut. Series of future climate data coupled with the calibrated crop growth model APSIM were then used to simulate impacts of climate change on crop production and evaluate adaptation options of crop management, such as planting date, fertilization and choice of variety. We found that temperature and the total number of dry days within the growing season had significantly increased over the 1965-2005 period. These climate changes reduced cotton yields, but no significant relationship was found for sorghum or groundnut. Predicted future changes in climate are in line with the historical changes. By mid-century, predicted maize grain yield losses under current farmer's practice are between 51% and 57%. For millet average yield losses are between 7% and 12%. A major challenge of adaptation strategies to climate variability and change is to match the crop growth cycle to the length of the rainy season. If crop management is improved – to avoid delays in planting date, to increase rates of fertilizer use and to use the best performing crop varieties – the loss in crop yield due to climate change can be compensated and even turned into a yield increase compared with current yields.

96. Use of regional climate model output for modelling the effects of future extremes in agriculture

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A growing number of high-resolution regional climate change simulations are publicly available through the WCRP CORDEX project, particularly for Europe. The so-called Euro-CORDEX simulation domain has a grid distance of around 12 km, and a large number of meteorological fields are available on a daily basis for each grid point. Simulations typically go from 1961 to 2100, following global model simulations with future emissions of greenhouse gases compatible with the IPCC scenarios RCP4.5 or RCP8.5.
In order to make the data useful for agricultural modelling, there is a need for bias correction of such data. As a first step, daily maximum and minimum temperatures as well as precipitation have been corrected towards the ENSEMBLES E-OBS gridded database of observational data. This has been done with a quantile-based correction, such that simulated present day fields are adjusted to reproduce the point-wise probability density functions of observations. The same correction is then applied to the simulated future.
Currently, a dozen simulations for each emission scenario are publicly available. In order to select a sub-set of these simulations for further use, a set of precipitation-based extremes indices have been calculated for south-western Europe. Through a principal-component analysis of models and index changes, four simulations have been chosen, one central and three as different as possible.
This study will be extended to countries outside Europe. A further step will be to use climate simulations to input crop and grassland models for impact studies on agricultural production.

97. Drought resistant and resilient plant functional types can maintain production in intensively managed grassland

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Droughts are predicted to occur more frequently in Europe due to climate change and are expected to impair intensively managed grasslands. To identify drought resistant plant functional types (PFTs), we established a common precipitation manipulation experiment in Switzerland (two sites) and Ireland (one site) with monocultures of four model plant species. The species (*Lolium perenne* L., *Cichorium intybus* L., *Trifolium repens* L., *Trifolium pratense* L.) represented different PFTs, defined by the combination of traits related to rooting depth and symbiotic dinitrogen (N_2) fixation. A nine-week summer drought with complete rain exclusion was simulated using rainout shelters, and aboveground biomass production during the drought period and a following recovery phase was compared to a control under ambient precipitation. In general, only insignificant changes in aboveground biomass production were induced after four to five weeks of drought, but considerable negative drought impacts were apparent after nine weeks (Switzerland: -39% biomass change under drought, Ireland: -85%). In Switzerland, the two N_2 fixing PFTs were significantly less impaired by drought (-18%) than the two non-fixing PFTs (-60%), whereas in Ireland, only the deep-rooted *C. intybus* was able to counteract drought to some degree (-57%), while the other three PFTs were impaired by -94%. After the six-week recovery phase, almost all drought stressed PFTs reached the production level of the control or even compensated for the former drought impairment, except the two N_2 fixing PFTs in Ireland. As a result, over both drought and the recovery periods, a negative net drought effect was only apparent for one PFT at each Swiss site and for the two N_2 fixing PFTs in Ireland. We conclude that, depending on PFT and site, droughts can impair aboveground biomass production on intensively managed grassland to different degrees. Growing a combination of drought resistant and resilient PFTs can promote forage production under variable climate conditions.

A contribution to the research leading to these results has been conducted as part of the AnimalChange project which received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) under the grant agreement no. 266018.
N.J.H. was funded by the Irish Research Council, co-funded by Marie Curie Actions under FP7.

98. Phenotypic variation among and within thirty accessions of Onobrychis viciifolia examined under climate change scenarios

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Sainfoin (*Onobrychis viciifolia* L.) is a highly beneficial forage legume for climate change mitigation and adaptation options. The mitigation potential is due to its ability to reduce greenhouse gas (GHG) emission by both replacing industrial fertilizer with biological nitrogen fixation and reducing methane emissions from ruminants. The adaptation potential stems from sainfoin being a very drought-tolerant crop. By being a regional European protein source, it also reduces dependence of global soy imports.
We tested thirty accessions of sainfoin to assess the existing variability in yield, morphological features, and levels of bioactive compounds (mainly proanthocyanidins (PA)), which are responsible for the methane reduction. These accessions came from a wide range of geographic origins and included a range from wild accessions to cultivars. They were planted together with alternative common forage species to test their suitability for climate change (extreme drought stress with 18 weeks of total rain exclusion).
For the evaluated agronomic and chemical traits, a large phenotypic variability was found, both within and among accessions. Yield losses resulting from drought ranged from 0 to 90%, with a mean of 25%, thereby partially outperforming Lucerne (*Medicago sativa* L.)(-22%) and chicory (*Cichorium intybus* L.)(-66%), two crops known to be highly drought tolerant. Chemical analysis uncovered a large range of PA concentrations with means of accessions between 23 and 47.5 mg PA / g dry matter (DM) and single plants ranging between 10.4 and 62.6 mg PA / g DM. Time of harvest and drought stress affected PA concentration, with time of harvest increasing PA concentrations in leaves by a factor of 2, while drought stress resulted in a roughly 30% increase in PA concentration.
In conclusion, sainfoin has a great potential for adaptation and mitigation of climate change. The phenotypic variation observed in this study constitutes a promising starting point to further improve agronomic and chemical traits of sainfoin by breeding.

This work has been funded by the LegumePlus project, which received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) under the Marie Curie Initial Training Network grant agreement no 289377

99. Participatory assessment of vulnerability to climate change for improved adaptations to climate smart agriculture

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Climate change is a global phenomenon affecting various sectors such as energy, transport and agriculture. In agriculture, climate change impacts have affected crop yields which are evident from increasing temperatures, decreasing number of rainy days and low humidity. Climate change has not only environmental dimensions but also social, economic and gender dimensions where most stakeholders are the poor and marginalized, particularly women with low socio-economic status. The adaptive capacities of poor and disadvantaged to climate change were reported as low, which makes them highly vulnerable to climate change. A participatory and qualitative study on vulnerability to climate change in agriculture was carried out using concept mapping technique, a technique developed by Trochim in 1986. Concept mapping is visual representation of how different ideas are related to each other. It is a structured activity which keeps a group on task and aware of where they are in the process. The Methodological framework of concept mapping comprises brainstorming, card sorting, rating, point mapping, cluster mapping, labelling and conceptualization. Structured process was applied to assess vulnerability to climate change impacts in agriculture in Anantapur district of Andhra Pradesh. The outcome of the study had indicated that vulnerability at household level has been categorized into social, livelihood, institutional and nonfarm focus dimensions. Women groups showed a more significant vulnerability to drought impacts in all aspects of social, institutional and nonfarm perspectives than men groups. Men and women groups differed significantly in rating the importance of each of the vulnerable category. The study has clearly pointed out the need for inclusion of gender perspective for development of adaptation measures that meet both gender needs while such adaptive planning brings ushers in a climate smart agriculture.

100. Adaptation strategies for livestock production systems in a changing environment

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The inter-tropical zone counts a majority of smallholders for whom livestock rearing is the family's food self-sufficiency. These smallholders are vulnerable to variations in productions, inputs and products prices caused by a changing environment, endangering their food security. One line of research is to utilize animal and plant resources diversity as a lever for livestock adaptation in hot regions to maintain and increase the production systems and farmers' economic benefits in a changing environment. Heat stress on animal, drought on forage production and increase in raw materials prices are part of the main constraints to ruminant systems in hot regions. Studies, through THI analysis, were conducted on the genetic potential expression of different cattle breeds in Mayotte and on forecasts of livestock production zones in 2050 in Australia. Adaptation strategies against heat stress are to migrate animal to regions less prone to heat, create options to cool the animals (water sprays, showers or isolation) and maintain local breeds' presence and shift to other cattle breeds more resistant to heat stress. Regarding adaptation strategies to drought, studies carried out in Australia and Madagascar suggest a better pasture management through harvest and forages conservation, multi-species pastures, grazing rotation and selling animals before dry periods. Markets fluctuations and uncertain environments lead to the promotion of recycling and limitation of wastes along the production chain while reducing the impact on the environment by substituting mineral fertilizers with livestock production effluents. The evaluation of cost-benefit relations of the different adaptation methods is still a key question for the future as well as the development and the spread of the management tools allowing assessments and monitoring over time of crops and animals performances, particular in contexts with poor references.

Acknowledgement: European Union, Reunion Island Regional Council, French Government and CIRAD for financial support.

101. Impact of climate extreme and variability on agriculture: a case from mountain community of eastern Nepal

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The lack of widely available data related to impact of climate change at local levels in Nepal has rendered national efforts to make the country climate-resilient a difficult challenge. It is, therefore, the specific drive of this study to assess the scenario of climate change, to analyze its impacts on agriculture and to record the autonomous adaptation practice by local farmer at Namsaling Village of Nepal. For the observed change in climatic variables, data of nearby stations were used. For future climate change scenario, output of Regional Climate Model, PRECIS, was used for developing climate scenario for 2040-2070. For the socioeconomic data-questionnaire survey, key Informant interview and focus group discussion techniques were used. The analysis of temperature data revealed that there has been a clear warming trend in the past temperature records; and maximum temperatures were increasing faster than the minimum temperatures indicating a widening temperature range. The rising trend of the temperature is seen in all seasons. There are increases in warm nights and warm days and cool days are decreasing. Summer days show significant increasing trend. Numbers of heavy precipitation days show an increasing trend. Analysis of the future projected data, the annual mean temperature and total annual precipitation are found to increase in 2040-2070 in comparison with baseline period of 1970-2000. These changes in climatic parameters may have a substantial impact on the agriculture and then livelihood of people. Cardamom and Ginger cultivation, which are the important cash crops, have now been shifted to higher altitude because they have been severely affected by pests at lower altitude. The native grasses have been greatly affected by the invasion of new grasses. Many people have replaced cultivation of food crops by cash crops now days. The local people are adapting to this change by making changes in their lifestyles. They have changed the time of sowing, cultivation and harvesting. They have also changed the crop species, ways of cultivation, irrigation type as well as crop type.

102. Analyses of extreme weather events and its impact to agriculture smallholders in Gandaki River Basin of Nepal Himalaya

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Extreme weather events have received significant attention in recent years since they have greater negative impacts on human and environments than changes in climate means. In recent years, those events have emerged as a source of vulnerability for agro-livestock smallholders in Nepal where people are mostly dependent on rain-fed agriculture and livestock farming for their livelihoods. One of the severe examples is that in the year 2013 all households of Dhe village of Nepal had to be relocated due to acute shortage of water caused by erratic rainfall and prolonged drought. To understand the risk of these events, we analyzed the temporal and spatial pattern of extreme events in Central Nepal. Results show that there is increase in percentage of warm days and nights and decrease of the cool nights and days. The magnitude of the trend is high in mountainous region. Trend of high rainfall days was found increasing with decreasing number of rainy days. Most areas are characterized by increases in both severity and frequency of drought and are more evident in recent years. The summers of 2004/05/06/09 and winters of 2006/08/09 had the worst widespread droughts and had a serious impact on agriculture production since 1981. In 2009 production of wheat and barley, the two major winter crops, decreased by about 50% in comparison to the previous year and 66% of rural households experienced food shortages, with the worst hit in the Mountain. During the same period, mountain communities reported that decreasing and erratic rainfall patterns and drought are the most serious hazards for agriculture. Livelihood vulnerability index shows that agro-livestock smallholders of mountain region are more vulnerable than lowland as the climate indicators are pulling the index up. Poor households without irrigated land are facing greater risks and stresses than well-off people. Better understanding of these dynamics of extreme events could help to develop effective mitigation strategies.

103. Developmental competence and expression pattern of heat shock protein genes in buffalo oocytes during heat stress

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Heat stress has a negative effect on mammalian reproductive efficiency. Buffalo, the principal dairy animal of India, contribute over half of the milk production in the country. Although, buffalo are very well adapted to hot and humid climatic conditions, but adapting to the changing climatic conditions, mainly heat stress, has resulted in their impaired productive and reproductive performance. Therefore, present study was conducted to evaluate the effect of heat stress on the developmental competence of buffalo oocytes obtained from abattoir through in vitro fertilization (IVF) technology and gene expression studies. Buffalo ovaries were collected from an abattoir and washed thrice with isotonic saline. The recovered oocytes were classified into 3 groups to be matured at elevated temperatures of 40.5˚C and 41.5˚C in groups of 15-20 in standard maturation (IVM) medium for first 12 hours and subsequently at 38.5˚C for remaining 12 h in a humidified CO_2 incubator. The third group was allowed for IVM under optimum temperature of 38.5°C for complete 24h maturation period. All the matured oocytes were fertilized separately with the buffalo freeze-thawed semen for about 16-18h. Cleavage rate and blastocyst yield was recorded at the end of this experiment. In a separate set of experiments, oocytes were analyzed for primers of heat shock protein 70 superfamily (Hsp70.1, 70.2, 70.8) and Hsp60, Hsp10 and Hsf-1 using quantitative real time PCR and the fold change was calculated. Results indicated that the proportion of above said cell stages was significantly higher ($p<0.001$) in control group compared to experimental groups. Overall, the blastocyst yield was significantly higher ($p<0.001$) in control group (13.2±0.33) compared to the experimental groups. Heat-stress induced higher expression of heat shock protein genes more than 2.5 fold. This study concludes that buffalo embryonic developmental competence gets highly compromised during heat stress, right form oocyte maturation through fertilization up to blastocyst formation. This indicates the carryover effect under stressed maturation conditions that remains persistent up to the blastocyst stage. Therefore, in tropical countries like India, climate change is undoubtedly affecting the fertility of livestock thereby affecting animal production systems.

Acknowledgements: The authors are thankful to NICRA project for financial assistance.

104. Heat tolerance in wheat identified as a key trait for increased yield potential in Europe under climate change

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To deliver food security for the projected 9 billon population in 2050, a 70% increase in world food supply will be required. Projected environmental changes emphasises the need for breeding strategies that delivers both a substantial increase in yield potential and resilience to extreme weather events such as heat waves, late frost and drought. Heat stress around sensitive stages of wheat development has been identified as a possible threat to wheat production in Europe. However, no estimates have been made to assess yield losses due to increased frequency and magnitude of heat stress under climate change. Using existing experimental data, we refined the Sirius wheat model and incorporated effects of extreme temperature during flowering and grain filling on accelerated leaf senescence, grain number and grain weight. This allowed us, for the first time, to quantify yield losses resulting from heat stress under climate change. We used the refined Sirius to optimise wheat ideotypes for CMIP5-based climate scenarios for 2050 at 6 wheat growing areas in Europe with diverse climates. The yield potential for heat-tolerant ideotypes can be substantially increased compared with the current cultivars in the future by selecting optimal combination of wheat traits, *e.g.* optimal phenology and extended duration of grain filling. However, grain yields of heat-sensitive ideotypes were substantially lower and more variable in Hungary and Spain, because the extended grain filling required for the increased yield potential was in conflict with episodes of high temperature during flowering and grain filling. Despite much earlier flowering at these sites, the risk of heat stress affecting yields of heat-sensitive ideotypes remained very high. Therefore, heat tolerance in wheat is likely to become a key trait for increased yield potential and yield stability in southern Europe in the future.

105. Is livelihood diversification Climate-Smart Agricultural strategy? Micro-evidence from Malawi

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Climate variability associated with farm-income variability is recognized as one of the main drivers of diversification in developing countries. Analyzing determinants of diversification to better understand household strategic behavior in the event of climatic risks and other shocks is of utmost importance for the formulation of development policies in developing countries highly dependent on rain-fed agriculture like Malawi. This paper investigates factors that impact diversification decisions and subsequent impacts on welfare, focusing particularly on the impact of climate variability. We use geo-referenced farm household level data collected in 2011 from a nationally representative sample in Malawi. The results show that measures of climate risk generally increase diversification across labour, cropland and income indicating that rainfall riskiness is a "push" factor for these indices. Our results also reveal that "pull" factors such as household wealth and education status of the household generally increase diversification across labour, land and income. Results also show that vulnerability to poverty is lower in environments with greater climate variability. Availability of services and support from rural institutions tend to increase diversification and reduce vulnerability to poverty. Looking at welfare measures as a function of diversification indices, all three measures of diversification increase consumption per capita, but income diversification has the strongest impacts on current consumption per capita and in reducing vulnerability to poverty.

106. Prospering rural vulnerable despite climate change: implications for "Triple Win"

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Climate change has posed several vulnerabilities to agricultural system globally. Rural resource poor are exposed to food insecurity due to slow adaptation measures against climate change. In addition, poor adaptive capacities are impeding mitigation of climate change. Resultantly, vulnerabilities are increasing over the period of time. In South Asian region, Pakistan is anticipated as significant contributor in global economy building. However, Pakistan is among the top 3 climatic vulnerable countries of Asia. Back-to-back floods, erratic rainfall and mounting temperatures are evident, causing loss of millions. Present research using cross-sectional survey research design was conducted in flood-prone areas of Pakistan. Both quantitative and qualitative methods were used to collect data. Analysis highlighted slack awareness and understanding about climate change. Almost cent percent farmers viewed climate change as natural process destined by God. A general concept among farmers was that weather is suddenly changing, rains are unusual and cropping patterns are changing affecting the productivity. Talking about mitigation, growers regretted that they have no mitigation measures such as weather resistant varieties. In addition, poor adaptive capacities don't permit the adoption of persisting expensive technologies. Natural disasters and agricultural loss has already diminished the prosperity in affected areas and poverty, food insecurity and malnutrition are widespread. Growers rated role of public & private sectors, extension work and availability of farmers' facilitation in terms of aid to be below the mark. Global partnerships, crop insurance, early warning systems and extended awareness campaigns are in dire need to mainstream growers towards climate smart agriculture. Before promoting climate smart agriculture, it is needed to make farmers smart via extension advisory services to adopt technologies for climate mitigation to ensure better productivity for global food security achievement.

107. Participatory climate risk management at short-term and seasonal scales – examples from South Asia

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Managing current climate risks is a practical adaptation response to build adaptive capacity at various levels to cope with increased variability and change. We present learnings from two projects undertaken in India and Sri Lanka to manage risk from short-term weather and seasonal climate forecasts. In participatory engagement processes with farmers and stakeholders across the value chain, we developed tools and methods to assess and manage short term weather-related climate risks. Tools such as a location-specific seasonal rainfall visualiser to understand the evolving season in combination with new sowing rules have been useful for farmers to deploy different risk management strategies. This work is now embedded in farming communities through facilitation of village level farmer climate clubs and climate information centres. Climate information centres use both analogue and information and communication technology (ICT) tools to make information accessible to a larger number of farming communities beyond the case studies. At a seasonal scale, we used a number of methods to value uncertain probabilistic seasonal climate forecast information in agricultural decision-making both at farm scales and beyond farm across the value chain. Using a value chain analysis approach, we identified the differential value of climate forecast information to decision-makers across the chain so information could be better tailored and targeted to improve efficiencies and eventual impact. We developed a decision analysis method that used a choice-chance-consequence approach providing useful insights on the value of forecasts using a simple spreadsheet-based tool. A social network analysis approach helped to identify key information sources or nodes for efficient, targeted dissemination of seasonal climate information to maximise outreach impact. The innovative, well-grounded and participatory approaches taken in these research projects have made an impact in the policy domains leading to encouraging outscaling and upscaling demands on the outputs of this work.

108. Establishment of dynamic-transfer system for agro-climate knowledge and farmers' response

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Egypt is very dependent on natural resources that are vulnerable to climate change. A large portion of the arable land in Egypt is particularly vulnerable to a rise in sea level. The climate risk aspects and impacts of climate change on new rural settlement communities are fairly well-known and documented. Also, adaptation of agriculture sector in Egypt to climate change necessitates modest efforts and steps in scientific research, mitigation and adaptation. The level of awareness shown by farmers in Egypt is still low. A major challenge to researchers, civil society and policy makers in the quest for innovative approaches to agricultural adaptation to climate change in that region, is to involve farmers and learn from the adaptive measures they must be practicing. Agricultural activities are closely related to climate variability and weather factors. The climate of a given region determines the type of crops, management systems, and finally the cash return of the unit area of the land. The effect of climatic factors on agriculture and natural resource management is evident. Agriculture is not only affected by the macroclimate, but also by microclimatic variation. Climatic factors affect the crop water requirements, time of cultivation, length of crop stand in the field, tolerance to pests and diseases, economic viability of agricultural production, and finally the total yield and product quality. The starting point of any agricultural development is to understand the prevailing climate condition. The use of climatic data could help in providing tools for proper management. The proposed system is to enhance and develop an online agro-information system according to the sustainable development aspects in the agriculture sector in Egypt, especially for small-hold farmers in new settlements. The system shows that existing mobile or other proper technologies have the potential to have significant impacts on rural economies. Innovative use of these technologies can address significant challenges facing Egypt's rural economy and have a positive impact on its farmers and their families.

109. Empirical assessment of climate change on major agricultural crops of Punjab, Pakistan

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Global warming is playing crucial role in pattern of climate change, which affects agricultural productivity. The objective of present study is the empirical assessment of climate change on three major agricultural crops of Punjab province, Pakistan. Cobb-Douglas type production function is used as functional[1] form. Cross-sectional data of the districts of Punjab for the period 1981 to 2012 are used. Fixed Effect with FGLS method is used. Overall findings of the study reveal that temperature has positive impact during first and third stage on wheat production while during second stage its impact is negative. Rainfall during all three stages has negative association with the production of wheat crop. Rainfall, minimum temperature and humidity during first stage have positive effect on rice production while during a third stage these variables have a negative impact on crop production. Rainfall during second stage has negative effect on rice production. Rainfall during all three stages of cotton crop has positive impact on its production. Effect of increase in temperature during first and second stage of cotton crop is negative on its production but during third stage it has a positive impact. On the basis of analysis, this study suggests that for the protection from negative impacts of climate change, government should conduct seminars and workshops for the awareness of farmers. Moreover, development of new varieties and allocation of more resources should be encouraged to provide security against the problems of climate change.

[1]Mahmood *et al.* (2012) also used production function form to check the impact of temperature and precipitation on rice productivity in rice-wheat cropping system of Punjab province.

110. Perceptions on climate change and impacts on ecosystem services in eastern Africa: implications for policy actions

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In recent years, communities, especially farmers, have started to experience the multifaceted challenges of providing food security for a growing population by supplying its demands for various food crops, while ensuring the integrity of ecosystems. Climate change is altering their farming environment; changing temperatures and precipitation patterns are affecting crop growth, livestock performance, water availability and the functioning of ecosystem services. It is important to acknowledge that farmers have their own ways of perceiving and understanding these dynamics. Communities' perceptions on climate change and its impacts on ecosystem goods and services are of research importance to inform climate change initiative processes or future policy actions in Tanzania and Kenya. This information would have a bearing on the future adaptation, mitigation and motivations for various stakeholders to support future policy actions. A field survey was conducted along altitudinal gradients of Mount Kilimanjaro in Tanzania and Taita Hills in Kenya. The objective of the survey was to assess communities' perceptions and knowledge on climate change and ecosystem services in order to provide information for policy actions. Data were collected through focus group discussions, household questionnaire interviews and transect walks. Results show that all the participants in the survey were aware of the climate change and they were able to give the indicators and impacts of climate change. The survey also identified a number of ecosystem goods and services available in the study areas. Findings further show that farmers are innovatively diversifying their sources of livelihood, from solely farm to combined farm and non-farm sources, with climate change. To cope with climate change, the study recommends some policy actions including support for livelihood diversification, mass education on environmental conservation, strict enforcement of legislation governing exploitation of ecosystem services and mainstreaming climate change into all developmental policies at local, national and international levels.

111. Irrigation management of salt water: study of potato and pea grown in intercropping with olive in southern Tunisia

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This work is devoted to the study of irrigation management with saline water of potato and peas cultivated between the olives trees in arid areas. The objective is to develop irrigation management strategy of these crops allowing the optimization of crop and irrigation water productivity management. Experiments were carried out in a commercial farm on fall potato and peas cultivated in intercropping system with olive-trees on a sandy soil and drip-irrigated with water having an ECi of 6 dS/m. Three irrigation treatments were applied: the first treatment (SWB100) consisted in providing 100% of Etc of annual crop. The second treatment is irrigated at the same frequency as treatment SWB100, but with quantities equal to 60% of crop water requirements (DI60). The third treatment (FM) was irrigated according to farmer irrigation practice. The experimental results show that SWB100 treatment reduced the soil salinity. However, DI60 and FM treatments increased soil salinity. Plant growth, dry matter, yield and its components were highest under SWB100 treatment. However, deficit irrigation treatment (DI60) increased soil salinity and reduced significantly potato and peas yields. A higher salinity associated with deficit irrigation caused important reductions in ground cover, stomatal conductance, net photosynthesis and yield components. Water productivity was affected by irrigation treatments. Water use efficiency for potato and peas production obtained under deficit irrigation treatment (DI60) is significantly different with SWB100 and FM treatments. The low efficiencies were observed for treatment FM, while the highest values were obtained with treatment DI60.

Results indicate that SWB100 treatment seems to be an adequate irrigation strategy for potato and peas production between olive-trees under the arid conditions of Tunisia. In case of situations where water supply is limited, potato and peas irrigation water requirements could be reduced by adopting a deficit irrigation strategy DI60 with a reduction of water supply by 40%. The deficit irrigation treatment (DI60) saves large irrigation water amounts (40%) and improves water productivity but with potato and peas yield losses of about 23 and 14%, respectively.

112. Assessment of the variability of yield of maize in Lilongwe district in relation to climate using DSSAT model

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Background: The focus area was Lilongwe district specifically Chitedze Research Station which lies at 13058'S and 33058'E; and altitude of 1146m. Chitedze falls in the mid altitude areas with annual rainfall of 800mm-1200mm, well drained sandy loam soils classified as Alfisols.
Aim and objective: The overall objective was addressing how climate change and variability may affect crop production in Lilongwe District, Central Malawi.
The specific objectives:

a) To assess the historical effects of climate variability on yields of maize.
b) To apply DSSAT to simulate yields of maize.
c) To assess the effect of time of planting on maize yield in relation to climate variability.

Materials and methodology: Secondary data on maize cropping systems and soil characteristics were reviewed from literature. The sources of information included Chitedze Agriculture Research Station, libraries (Bunda College and Chitedze Agriculture research Station), ICRISAT, Ministry of Agriculture and Food Security, selected Extension Planning Areas (EPAs) in Lilongwe; Lilongwe Agriculture Development Division, Lilongwe District Agricultural Office, and scholarly articles and Climate data for the previous 30 years were accessed from the Department of Climate Change and Meteorology Services of Malawi. Solar radiation, daily rainfall, relative humidity, sunshine hours, minimum and maximum daily temperatures data were accessed. This data was complemented by data from NASA web portal and analyzed using simple excel graphs and DSSAT model was used to run the model as well as helped in answering objective number three of changing the planting dates to see how they affected the yield of maize for the study site.
Results: For objective one, overall, the trends indicate variability of rainfall patterns over a 12-year period and this affected planting dates hence all these changes in planting dates and months were partly due to continuous shifting of the rainfall patterns with later rainy onset in most of the areas in the country and earlier cessation in all areas. The results also show that there was a direct relationship between the yield observed when total dry days, total wet days and seasonal rainfall received are factored in, not annual rainfall amount. This is so because the annual rainfall amount does not give a true picture of when the planting rains came, as it does not consider the rainfall onset and cessation day. Yield of maize is affected by rainfall variability, especially by the total dry days, total wet days and seasonal rainfall of the different cropping season. The total dry days, total wet days and seasonal rainfall provides coherent evidence in terms of the spatial distribution of rainfall over time.
Whilst objective two, the DSSAT model was able to simulate yields for Chitedze Research Station, as the observed figures were close to those simulated using the model. The last objective which put much emphasis on agronomic management practices, such as different planting dates, indicates that planting maize early December increase maize yields with low yield reduction (9.59%). Overall, the results show that planting early December (15th December) and late December (30th December) there is not much difference in terms of yield. Smallholder farmers obtain optimal grain yields if they plant on early and late December.
Conclusion: Smallholder farmers in Chitedze and areas with similar agroecological conditions should be encouraged to plant maize early December (1st half of December) to attain high yields. From the first half of December until March there is considerable amount of rainfall over an appropriate numbers of days to support crop growth and development. The research should be conducted at field-level in a number of districts, to assess the effect of variable rainfall patterns on yield. The model needs to be calibrated to local conditions. Most of the data required by the DSSAT are not easy to find, hence there is a need for scientists to collaborate in order to come up with reliable results and make the DSSAT efficient.

L2.3 Combining mitigation, adaptation and sustainable intensification

113. Agricultural intensification trajectories and climate smart agriculture in Nicaraguan tropical systems

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Agricultural intensification (AI) has been adopted as the main strategy to increase agricultural production. The two main trajectories of AI are a) energy-intensive agriculture characterized by large labor-efficient farm operations in order to increase food production per unit energy, and b) agroecological intensification that integrates ecological principles into farm systems management, uses local knowledge and networks, and optimizes welfare rather than only production. Climate smart agriculture and sustainability of rural farms are strongly related with these trajectories. This study will analyze which AI trajectories better characterize agricultural systems along a tree cover transition (TCT) in Nicaragua. We expect that agroecological intensification will be more common in areas with higher forest cover, whereas energy-intensive intensification will be more important in areas with lower forest cover. Financial and biophysical information at a farm level will be collected for 180 farms in 3 municipalities in Nicaragua: La Dalia, Waslala and Siuna, sites that exemplify different degrees of forest degradation. Selected farms will represent the most common farming systems in the study region. Additionally, focal groups will be used to build indicators of sustainability based on three dimensions: income for farmers, social sustainability, and ecosystem properties. Using multivariate statistics, we will build indices of energy-intensive and agroecological intensification at farm level. Our results will provide a holistic characterization of farming systems, identifying the limits and opportunities for farms to develop climate smart agriculture and sustainable production as tree resources decrease. This information will be used by policy makers for potential entry points for developing policies and investment strategies to improve sustainability of agricultural landscapes.

114. Value of estimating farm GHG budgets making use of process-based modelling

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Generic estimates of greenhouse gas (GHG) emissions are often applied when making GHG budgets in whole farm models. The aim to become more specific implies more detailed methods are needed. Process-based models aid to unravel which key mechanisms are involved with variation in GHG emission. Process-based models generally describe a single farm component (enteric fermentation, manure, soil). Furthermore, they require more specific inputs which makes their use more complicated and increases the number of input uncertainties to be handled (in order of increasing uncertainty of inputs: digestive/enteric fermentation models, manure storage models, soils/crop models). Their combined use (by combining their inputs/outputs), however, offers unique and detailed insight into the biotic and abiotic mechanistic drivers of GHG emissions. These models enable to explore the complex relationships between farm activities and GHG sources, and their mutual interaction (synergies/trade-offs). Furthermore, a clear advantage is that insights are less sensitive to the empirical basis used to develop them than the more generic empirical approaches to estimate GHG emission. Farm-level models may benefit from the insights from process-based models by an improved coverage of observed variation in GHG emissions, which is highly relevant when specificity is demanded. Such benefit and the need for more specificity is demonstrated by an evaluation of the GHG budget calculated with process-based models for several farm cases that differ in the intensity of feeding, grazing and N fertilization.

115. Farmer's perceptions on climate change and prospects for climate smart agriculture along the tree cover transition curve

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The combination of social and ecological factors determines people's vulnerability to climate change (CC) and options for climate smart agriculture. This study uses the tree cover transition curve framework (TTC that links reforestation stages of landscapes to a preceding deforestation process), to understand how adaptive capacity and perception on CC vary as agricultural systems develop and tree resources decrease. We selected 3 sites in Nicaragua (Siuna, Waslala and La Dalia) to represent tree cover decline phases (from early degradation: Siuna, towards sites with low tree cover: La Dalia) and Hojancha-Costa Rica to represent recovery phase. We characterized 140 households per site with a household survey (www.ccafs.cgiar.org). Different sets of 45 indicators (*e.g.* livelihood capitals, food security, land use, farm size, and CC induced changes in farm management) were used in 4 cluster analyses to explore how farm types (land use allocation, CC perceptions, adaptive capacity and available tree resources) vary along the TTC. At early degradation and recovery phase, extensive cattle ranching and basic grains dominate, there are few progressive CC-induced changes in farm management (but high impacts of extreme events in Siuna), good adaptive capacity and good food security. Intermediate phase is similar to early degradation in land use and CC perception, but with the lowest adaptive capacity. In agricultural landscapes where basic grains smallholders agriculture predominate, most farmers have changed farm practices due to progressive CC, have low to medium adaptive capacity and high food insecurity. Early and intermediate degradation landscapes offer opportunities for mitigation, fostering sustainable intensification; improving coping capacity of farmers there might offer triple wins. In landscapes with high pressure on land (La Dalia) options for mitigation are limited; efforts for improving adaptive capacity and alleviation of food insecurity are perhaps the only intervention strategies possible in the short term.

116. The Agritech Water Cluster – Promoting collaboration to manage future water needs of the agriculture sector

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The Agritech Water Cluster promotes the formation of new collaborations between academic researchers at the University of East Anglia, with industry partners in the agritech and water industries. This project explores how the agricultural industry will respond to changing water availability in the face of future challenges. With climate change, population increase and water resources already under pressure it creates restrictions on the increasing demand of water for use within agriculture. Eastern England is the driest region in the UK, yet contains 60% of England's irrigated agricultural land. The long-term threats of climate change include hotter, drier summers, increased likelihood of droughts, reduced water availability and increasing water demand. This raises concerns about the reliability of future water supplies, which is at the heart of the agricultural industry. From recent workshops covering future challenges, agribusinesses were often reluctant to invest in resilient infrastructure due to more immediate pressing issues such as changes in policy and the high upfront costs of solutions, leaving themselves vulnerable to future impacts. Engagement with industry stakeholders so far shows significant interest to increase the resilience of future supply and bring a fair share of water for agriculture in Eastern England through the development of a '25 year plan' for water across the agricultural supply chain. This is focused on Eastern England and its specific challenges such as irrigated agriculture and its sensitivity to climate change. Development of a 25 year resource plan requires a holistic approach to water management and the involvement of all individuals who use water.

117. Climate change mitigation and agricultural development scenarios for the high plains of Eastern Colombia

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Research and development efforts by CIAT and its partners in the high plains of Eastern Colombia and other parts of the tropics have led to the development of a concept for sustainable intensification of pasture-based agricultural production systems that we call "LivestockPlus". The key components of the concept are (1) land-use changes and practices that increase above and belowground carbon, (2) improving livestock production efficiency and reducing methane emissions through improved forages and management practices and (3) more efficient use of nitrogen through tropical forage cultivars that inhibit nitrogen loss. Our results for the Eastern plains showed that above and belowground carbon stocks could be increased through the use of improved pastures and silvopastoral systems. Proper stocking rates and more productive and high quality forage-based feeding systems can increase livestock productivity and reduce methane emissions per unit livestock product. Biological nitrification inhibition ability by improved forage grasses is shown to reduce nitrous oxide emissions substantially. We estimated the combined effects of these sustainable intensification practices on emissions and on agricultural development in the Eastern plains. Our results showed favorable environment–development trade-offs and some win-win scenarios. However, many barriers exist to the adoption of these improved land management practices and land use systems. We make suggestions for new research to address obstacles to realizing changes in knowledge, action and practices in the development of sustainable intensification in the high plains of Eastern Colombia.

118. Contributing to CSA progress through a national multidisciplinary research program on adaptation to climate change

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Progress in CSA implementation requires multidisciplinary investigations on the various dimensions of agriculture responses to climate change (CC). This presentation focuses on the theoretical framework and strategy of the 'Adapting Agriculture and Forestry to Climate Change' (ACCAF) metaprogram that the French National Institute for Agricultural Research (INRA) conducts. Since 2011 and for 10 years, ACCAF provides financial and human support to research projects, international networks and programs (*e.g.*, MACSUR or AGMIP, JPI FACCE actions), and to a many activities (*e.g.*, workshops, congresses, articles, books…). Projects combine multi-scale observation and experiments with integrative modelling, including economic assessment of options for adaptation. Emphasis is put on multidisciplinarity from biophysics to human sciences and on characterizing the various sources of variability (*i.e.*, soils, sites, stochastic climatic variability) and uncertainty (*i.e.*, Representative Concentration Pathway, lack of knowledge in climate or crop models). Targeted objectives include: (i) assessing and managing the risks and opportunities of climate variability and extremes, and developing strategies to face the impacts of climate crisis; (ii) elaborating scenarios for regional impacts of CC; (iii) understanding and managing the main effects of CC on agriculture; (iv) improving crops and livestock species and contributing to strengthen the adaptive potential of agricultural systems and supply chain; (v) developing innovative adaptation technologies compliant with mitigation strategies; (vi) assessing the costs and benefits of adaptation measures; and (vii) proposing collective organization frameworks that enhance adaptation potential. Through the involvement of partners from research, transfer and education, ACCAF contributes to build a new knowledge community on adaptation, to disseminate this knowledge towards various categories of end users and to advance CSA implementation.

119. Could agroforestry be a way to limit soil erosion susceptibility under a temperate climate?

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In European agricultural landscapes, conventional farming and climate changes can amplify soil erosion susceptibility. Recent policies have encouraged agroforestry practices that are believed to provide a number of ecosystem services and improve biodiversity. However, fundamental and applied research is still required to determine how best to plant and manage, depending on land use, climate and topography. Within this context, our project investigates the ecosystem services provided by crop/forest systems, in relation to soil structural stability. We chose to study the following variables: stability of soil aggregates, root traits and distribution, microbial activity and microbial metabolic diversity. The project involves eight field sites representative of different agro-forests which have distinct ages and pedoclimatic characteristics. On each site, a systematic sampling was performed to assess the influence of the tree row, the distance to the trees and the perennial plant cover on the variables listed above. The relationship between soil aggregates and functional traits of plants and soil microbes is studied with substantial field measurements involving a large network in French agroforests. The preliminary results of this project suggest that the tree row and the proximity of trees are beneficial for soil aggregate stability. This result is related to the quantity of roots. The magnitude of these effects seems however to depend on the characteristics of the agroforestry system. The results of this research should allow stakeholders and agroforesters to better determine adapted spatial management strategies with regard to plant root traits and erosion risks.

120. Scientific and policy recommendations for climate smart arable agriculture in Europe: lessons from the past decade

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The topsoil of arable soils is depleted in carbon compared to grasslands and forests. This management effect bears a significant potential for mitigation and adaptation via soil carbon sequestration, which also increases soil resilience to weather extremes. This presentation revisits the scientific and policy recommendations made for the European Commission since 2003 in light of new observations, global and European meta-analyses and model results achieved in the last decade.

Scientific understanding has much improved our understanding of the complexity and diversity of arable cropping systems in Europe and their potential for mitigation. All major policy recommendations about measures have remained valid. The magnitude of the carbon sequestration potential, however, has been somewhat overestimated in the past. But new findings suggest that carbon sequestration does not saturate for decades. There is new and much enhanced evidence that broad measures such as conservation tillage, intercrops and organic manure have a stronger role for adaptation than for mitigation. In contrast, greenhouse gas hotspots from drained and farmed organic soils and from the surprisingly frequent land-use changes in Europe require urgent action for mitigation. The opportunity to act on hotspots has been strongly underexplored so far.

Analyses of past agricultural and climate policies and the failure of a common European soil policy framework indicate that few of the recommended measures have been implemented in policies. Even fewer of the most effective measures have been actively implemented by farmers due to weak incentives and control. The recent reform of the European Common Agricultural Policy has again failed to promote strong coordinated efforts for mitigation and adaptation but offers new chances for measures at regional level. We discuss policy options that increase incentives for action.

121. Adaptation to climate change through land-use change in France and implications for greenhouse gas emissions

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Land use is a major component of adaptation to climate change in agriculture and other land-based sectors. As climate influences land returns that can be expected from various land uses, adaptation to climate change is likely to induce land-use changes. In this paper, we examine the impacts of the latter on greenhouse gas (GHG) emissions in France. The econometric models used in this paper build on a Ricardian framework, where land returns for each land use depend on climate, soil and geographic variables, and a micro-economic random utility model describing landowners' land use choices between annual crops, grassland, forest, perennial crops, and urban use. Data on land use are based on Teruti data (550,000 points surveyed each year in mainland France from 1992 to 2003). Land returns are derived from statistics on land prices, productivity and urban densities. Gaussian General Additive Models are used to estimate the relationship between land returns under each land use on the one hand, and climate (temperatures, precipitations, solar radiation, relative humidity and wind from Arpege downscaled at 8km resolution) and soil characteristics (soil depth, water holding capacity, slope, altitude) on the other hand. These relationships are then used in a multinomial logit model to estimate the probability that any plot is in a given land use. We then simulate land use developments until 2050 under a baseline and a climate change scenario (A1b). The impacts on soil carbon stock and GHG emissions are computed using data from the French GHG inventories. The results indicate that climate change may lead to large land conversions, in particular from grassland to cropland. Such land-use changes may be responsible for large amounts of CO_2 emissions. Our findings emphasize the importance of accounting for the interdependence between mitigation and adaptation due to land-use changes.

122. Mitigating GHG emissions from ruminant livestock systems

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Improving the net GHG budget of ruminant livestock systems without a reduction in productivity and economic sustainability, requires effective mitigation options in terms of abatement potential and costs. Grasslands and grassland management have a large potential to mitigate livestock GHG emissions at a low (or even negative) cost. A synthesis of eddy flux covariance data (*i.e.* 189 site years) shows on a mean net carbon storage equal to 0.76 ±0.1 MgC $m^{-2}yr^{-1}$, indicating a significant carbon sequestration of grasslands in Europe. Simple calculations showed that C sequestration of grasslands can compensate for other GHG emissions on site (*i.e.* enteric CH_4 and soil N_2O in CO_2e) by staying close/below a critical stocking rate and moderate fertilizer application. However, to implement these findings into effective mitigation options, in terms of technical feasibility, abatement potential and costs of implementation, Life Cycle Assessments are required. For France, a national abatement study has been dedicated to identify and assess mitigation options without production losses at farm level. In addition to grassland management, two other actions have been identified for livestock farms (*i.e.* ruminants): reduction of enteric CH_4 through addition of oilseeds or nitrates in the diet and reduction of nitrogen losses by decreasing dietary protein in dairy cows. The selected measures were quantified concerning their abatement potential and costs using a marginal abatement cost curve approach. In terms of unitary abatement potential (Mg CO_2e avoided per ha or head) the most interesting measures are: increase in %legume, reduction dietary protein and nitrate addition to diet. When implemented on national basis, the addition of oilseeds and the increase of legume fraction had the highest abatement potential. In terms of abatement costs (€ per Mg CO_2e) the most attractive measures are the extension of grazing season, increase in legumes content and a 10% reduction in fertilisation.

123. Global assessment of technological innovation for climate change in developing countries: opportunities and challenges

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The role of technological innovation cannot be overemphasised in view of growing concerns of climate change impacts in developing countries. The development and effective diffusion of new technologies will largely shape how poorest nations mitigate and adapt to climate change. Adaption and mitigation based on new technologies can help address climate change challenges particularly in agriculture sector and energy sector. Creating new technologies and harnessing them to allow developing countries to mitigate or adapt to climate variability and change particularly in the regions that are most exposed to climate change will require effective technology-climate innovation policies. As a first of its kind study, we assess the global status of four technologies such as integrated soil management practices, modern biotechnology, information and communication technology and renewable energy technology in developing countries. Using bibliometric and patent data analysis (Adenle *et al.*, 2013; Johnstone and Hascic, 2013), we indicate the degree to which capacity exists in terms of research and development in developing countries and emphasise the need for technology and integrated innovation policies for climate change toward green growth and sustainable development. A range of policy measures were emphasised for strengthening the linkages between public investment and private sector innovation to enhance low-carbon development pathway.

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124. Synergies and trade-offs of adaptation and mitigation on dairy farms

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Livestock farms with ruminants have large and diverse fluxes of greenhouse gases, but are also affected in diverse ways by climate change. This calls for assessments of possible options to mitigate GHG and to adapt to changing climate, primarily at the farm-scale. This study focuses on the effects of adaptation and mitigation options, and their synergies and trade-offs on GHG emissions and production on European dairy farms. Climate change will impact on livestock production systems in several ways depending on livestock type, system design and local conditions. These effects are direct through impacts on animal performance, for example heat stress, diseases and land accessibility, and indirect through effects on yield and quality of feed crops caused by changes in the thermal growing season, drought, heat stress and water logging. These impacts demand adaptations of farming systems to cope with the changed climate. Adaptation can be categorized in three main categories: feed production, feed supply (feeding) and livestock management. Several of these adaptation options have impact on greenhouse gas emissions and thus on the mitigation potential. There is therefore need to align measures for reducing greenhouse gas emissions with the likely adaptations to be adopted. Assessments of which adaptation and mitigation measures would likely be adopted for real and virtual farms mixed dairy farms has been determined. The virtual farms are created combining estimated data and information based on regional production systems and national statistics whereas the real-life data are collected on real farms. The climatic zones represented in the study are Maritime, Continental and Mediterranean. The second stage was to assess synergies and trade-offs between the adaptions and mitigation measures. This was based on general considerations combined with assessments by local experts.

The authors wish to acknowledge the financial support of the EU Project AnimalChange (FP7-KBBE-2010-4).

125. Land management practices as a coping mechanism to frequent and prolonged drought spells by smallholder farms

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The occurrence of prolonged drought spells is a major cause of crop failure in rain-fed agricultural systems. However, recent studies have shown little evidence of an increase in the length of such spells in the highlands of the Eastern Africa. A good soil rich in organic matter can retain water and withstand a dry spell for 20 days as compared to only 12 days for a degraded soil. This implies that crop production failure due to prolonged dry spells would be mitigated by improving the efficiency use of rainfall through the restoration of deteriorated physical properties of soil. Rain water use efficiency, soil water holding capacity, soil-crop-livestock interactions were evaluated under a range of land management practices including terracing, mulching, fodder and agro-forestry tree planting. Data were collected on a sample of 300 households before and after intervention in the Rwandan head waters of Kagera basin including Burera, Rulindo and Kamonyi districts of Rwanda. Terracing increased the fodder production per household per day five- to eightfold. Fodder and manure production per household increased with the number of terraces per household (R2 = 0.931 and 0.892, respectively), and 86% of sampled farmers get fodder from terraces. Terraces increased the yield of Irish potatoes threefold. Mulching coupled with manure and NPK fertilizer application increased the yield of four cassava varieties almost sevenfold. Bench terraces improved the soil water holding capacity from 40 mm to 78 mm. In addition, water productivity value of 27 kg ha^{-1} mm^{-1} $year^{-1}$ for Irish potato was recorded on bench terraces. Findings concluded that the package of land management practices increased the soil water holding capacity, the rain water use efficiency which in return enhanced the resilience of crops to prolonged dry spells.

126. Sustainable intensification of global maize cropping systems: balancing yield increase and nitrous oxide emissions

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Since most of the land suitable for agriculture is already in use, additional food is likely to be produced by increasing yields rather than through cropland expansion, unless further tropical deforestation occurs. Great opportunities for increasing crop yield exist in many parts of the world where low rates of fertiliser are currently applied. However, complex interactions between socio-economic and biophysical drivers of food production must be carefully analysed to comprehend the nature and the extent of challenges to future agricultural development. This study explores trade-offs between maize intensification through nitrogen (N) fertiliser and nitrous oxide (N_2O) emissions using the global crop model PEGASUS. We estimate an additional 332 $Gtyr^{-1}$ of maize could be produced on current rainfed and irrigated maize areas using intensive levels of N fertiliser, representing a 62% increase in current global maize production. In terms of N_2O emissions, current level of N application rates to maize harvested areas produce 91.6[24;406] 109kgCO_2eq, corresponding to an emission rate of 695[182;3,080] kgCO_2eq$ha^{-1}yr^{-1}$. Under higher N inputs, total N_2O emissions increase by 60%, reaching 147[38;654] 109kgCO_2eq with an emission rate of 1,115[288;4,962] kgCO_2eq$ha^{-1}yr^{-1}$. The range here represents uncertainties related to N_2O emissions factors estimated by the IPCC. We find efficiency of N application varies widely across regions suggesting that for some areas present trade-offs exist; increasing N fertiliser application produces a large positive response in terms of yield relative to N_2O emissions in parts of Africa, Asia and South-America. However, we find a lose-lose outcome for key maize producing areas including northeast Brazil and China, as well as poorer countries such as Nigeria and Tanzania, where increasing N fertiliser only – without addressing other limiting factors such as soil nutrients imbalance and water scarcity – causes negative results by raising N_2O emissions without enhancing crop production. Our analysis provides a comprehensive geo-spatial analysis of the effects of agricultural intensification on yield and N_2O emissions to better identify solutions for achieving sustainable intensification across the large diversity of agricultural and food systems in the world.

127. Temperature impact on CO_2 emissions and nutrients availability in Malagasy soils under different farming practices

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Temperature variations affects soil organic matter dynamics with serious implications on nutrient availability and greenhouse gases emissions from tropical soil. Agroecological practices, such as agroforestry systems or/and organic manure amendments, are considered as a sustainable practice in climate change mitigation and soil fertility improvement. In this context, a mesocosm experiment was carried out in order to assess the impact of temperature on CO_2 emissions, and on soil P and N bioavailability in Ferralsol under agroforestry and conventional systems at Madagascar. The experiment was a 59-day lab incubation at 25 and 35°C with and without manure addition. Kinetics of soil organic carbon (SOC) mineralization was characterized after CO_2 emissions, inorganic N (NO_3^- and NH_4^+) contents and P bioavailability measurements at different dates. Globally, SOC content, CO_2 emissions, P and N availability were higher in agroforestry than in conventional systems. Results showed that CO_2 emissions increased with temperature and manure addition in both farming systems. The Q10 index ratio, *i.e.* the temperature dependence of soil CO_2 emissions, was higher in the conventional (1.5) than in the agroforestry systems (1.2). Q10 unexpectedly increased after manure addition in both systems; respectively 1.7 and 1.5. Manure mineralization or the priming effect involved by manure addition seemed to be more sensible to temperature than SOM mineralization. Manure addition increased P bioavailability (+ 0.01 g P kg^{-1} soil), but temperature did not impact P bioavailability. Globally, N mineralization was more influenced by temperature and manure addition in conventional than in agroforestry systems. In conclusion, agroforestry farming and manure addition enhance N and P availability. Increasing temperature did not increase further P availability but enhanced CO_2 emissions and N mineralization. Agroforestry displayed smaller Q10 than conventional farming, but manure addition seemed to reduce that benefit.

128. The synergies of fertilization on carbon sequestration and food security in China

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Network of long-term field experiments including similar fertilization treatments has been in operation across different climatic zones since the 1980s in China, which provides solid scientific information for evaluating the role of fertilization management on carbon sequestration and food security in China. In this study, 518 time series observations from 39 experiment stations on annual crop yields and SOC stock changes in the top 20 cm soil layer for different fertilization regimes were collected and analyzed using Meta approach. The dataset includes staple crops, typical soil types and cropping systems in China. Results show that fertilization can enhance carbon sequestration in cropland with ranges of -40-139 kg C·ha^{-1}·yr^{-1} by chemical fertilizers, 155-719 C·ha^{-1}·yr^{-1} by organic fertilizers, 159-827 C·ha^{-1}·yr^{-1} by application of organic and inorganic fertilizers together, -4-432 C·ha^{-1}·yr^{-1} by returning straw to cropland. Fertilization also can increase the yield sustainability and decrease the yield variability. The yield sustainability increased and variability decreased with the increase of soil organic carbon stock. Compared with no fertilization treatment, yield increase rates (118%-186%) of treatments with organic fertilizer are much higher than those without organic fertilizer (35%-130%). Therefore, organic fertilizer application has potential to enhance soil organic carbon (SOC) stocks in cropland, with benefits for grain productivity, yield stability and climate change mitigation in China. Unfortunately, the tradition of application of organic fertilizer has been changed due to lack of labor of small scale farmers, few farmers raising livestock, and extra costs resulting from commercialization of organic fertilizer.

129. Adaptation to climate variability: evaluation of adaptation tools for the agricultural sector in Guanacaste, Costa Rica

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Central America is known as one area that is the most affected by climate change due to its geographic situation at the confluence of the ITCZ. Focusing on the Province of Guanacaste, a sensitive region of Costa Rica in terms of drought issues, the G8 Belmont project FuturAgua (https://futuragua.ca) believes in the importance of generating weather forecasts in decisional processes to improve drought resilience. The aim of this important project is to understand human and institutional answers to climate variability, and find solutions to support local actors in water resources management to fight negative effects of climate changes.
The goal of the present work is to study the answers of the agriculture sector to drought situations. We realized extensive farmers' interviews to establish the typology of production systems in the Potrero-Caimital and Sardinal Watersheds, as well as the farmer's perception regarding the usefulness of weather forecasts as a tool for adaptation to climate variability and extreme events. Based on this data and other information collected in field, we developed a simple bioeconomic model of a farm a la carte with the software GAMS which has 3 components:

- A set of fixed farm parameters with 5 modalities according to 5 types of year (extremely dry, dry, regular, wet or extremely wet): Inputs costs like seeds, fertilization or irrigation costs but also yields and market prices.
- Some constraints that can be changed according to the type of farm to be studied: land, capital, labor, food security (auto consumption) and risk aversion (minimal expected income).
- An optimization routine for the expected income of the farm based on farmer's decisions with and without forecasts and adaptation instruments (*i.e.* irrigation and insurance).

Simulations with the optimization model allowed us to assess the economic value of different instruments for the adaptation to climate variability, such as weather forecasts, irrigation and crop insurance.

130. Efficiently mitigating climate change through improved land management in smallholder agriculture of Malawi and Zambia

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Sustainable intensification aims to increase productivity through increasing input use efficiency, augmenting ecosystem services, and reducing pollution. Climate-smart agriculture (CSA) is one approach to achieving this, addressing the challenges of building synergies between the closely related factors of climate change mitigation, adaptation, productivity as well as income increase. While various agriculture technical solutions provide potentials to deliver CSA benefits, assessing which option is most efficient and synergetic in any particular context is a critical necessity for effective policy-making.

This paper presents an integrated approach for assessing the synergies between the mitigation potential, crop productivity and technology profitability of a larger set of improved land management practices in Malawi and Zambia. Practices considered include agroforestry, intercropping, crop rotations, residue management and reduced tillage.

Practices were assessed for their potential to lead to significant mitigation benefits. At a refined spatial scale, soil data from the Harmonized World Soil Database was utilized both to populate the Stehfest-Bouwman approach for field emissions of nitrous oxide, and to estimate soil carbon stock changes using the IPCC Guidelines. Further covered emission sources include ammonia volatilization, nitrogen leaching, crop residues, and fertilizer and pesticide production.

Using ad-hoc household surveys, a comprehensive estimation of the costs of the selected improved land management practices in different agroecological zones was developed, and farm incomes have been estimated.

Marginal Abatement Cost (MAC) curves relating the costs and mitigation potential of land management options were derived. The cost-effectiveness of different land management practices is proposed as synergetic decision criteria allowing policy makers to prioritize support interventions on the basis of the economic efficiency of GHG abatements.

131. Climate-Smart water and nitrogen management strategies for lowland rice

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World Nitrogen (N) fertilizer consumption is around 100 million metric tons and is expected to increase with growing food production. However, the N use efficiency with current surface application of urea is extremely low (35-40%) due to its losses from ammonia volatilization, nitrification, denitrification and runoff, particularly under flooded rice cultivation. N losses disrupt natural ecosystems, impair water quality and contribute to global warming (nitrous oxide [N_2O] emissions). Climate-smart technologies maximize synergies while minimizing tradeoffs associated with increased productivity and sustainable farmer income, reduced environmental pollution and reduced vulnerability to climate variability and risks. Technologies that reduce environmental footprint without sacrificing productivity, farmer income and sustainability are more likely to be adopted by farmers. Modified urea-N fertilizers and/or subsurface application have resulted in significant reduction in N losses and increased productivity. In Bangladesh subsurface application of urea – urea deep placement (UDP) – has increased rice yield by 15-18% while reducing N use by one-third compared with broadcast urea. UDP also resulted in significant reduction in N volatilization loss (<5% vs. 25-35% with conventional application) and N_2O emissions. N_2O emissions from UDP fields were as low as emissions from unfertilized N plots, ranging from 20-50 g N_2O-N ha^{-1} (wet season) to 100-160 g N_2O-N ha^{-1} (dry season). Moreover, the drudgery of deep-placement was reduced with the use of affordable applicators, and, combined with a single N application and reduced weeding, it decreased labor requirement by 15-25% compared to broadcast urea. UDP technology has proven to be an effective climate-smart agricultural practice that increases the food production and wellbeing of poor rice farmers and reduces GHG emissions through the combination of reduced N fertilizer use and reduced N losses. Preliminary results also show reduced N_2O emissions from UDP under alternate-wetting and drying conditions (AWD). The combination of UDP and AWD resulted in reduced N_2O and methane emissions, water saving and higher grain yield compared to continuously flooded conditions with conventional application of urea.

132. Storing C in agricultural soils: evaluating triple-win climate-smart actions for France

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Globally, soils contain three times as much C, present as organic matter; as does the atmosphere. Increasing C storage in soils is thus one of the strategies by which the agricultural sector can mitigate its net greenhouse gas emissions. In European temperate areas, climate change is expected to decrease precipitations and increase the frequency of drought events. Through its strong effects on soil water retention and infiltration, soil organic matter can also contribute to the adaptation of cropping systems to climate change. Moreover, soil organic matter contributes to yield stability by fostering soil biodiversity and supplying nutrients. Storing organic carbon in agricultural soils is thus considered as a triple-win climate-smart strategy (mitigation, adaptation, sustainable intensification).

Using France, with its typical intensive and diversified agriculture, as a case study, we identified cropping practices that would increase soil C stocks while maintaining productivity and without major changes in the current cropping systems. We considered three actions: reducing tillage, planting more cover crops in annual cropping systems, and developing agroforestry and hedges. We quantified the additional soil C storage potential per unit surface area induced by these practices based on a literature review. We then determined the applicability of the actions in mainland France and their C storage potential at the national scale. The actions considered have the potential to increase national soil C stocks by up to 2 Tg C y^{-1}, while maintaining production levels and increasing the resistance and resilience of soils and cropping systems to climate change.

133. Innovative cropping systems under GHG emissions constraint: results of a long-term field trial assessment

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There is a need for Innovative cropping systems (ICSs) that take into account both new environmental targets and current on-farm constraints. As all the components of agro-ecosystems cannot be integrated into present models, long-term field trials are necessary to assess new cropping systems. We are currently assessing ICSs aimed at reaching various environmental criteria, one of them corresponding to a decrease in greenhouse gas (GHG) emissions, and yield targets. Here, we present the results collected during the first complete rotation of this system.

The ICSs were designed in 2008. The PHEP ICS was conceived to meet various environmental criteria and reach high yield with no major constraint. The L-GHG ICS must simultaneously (i) meet a GHG constraint (*i.e.* halve GHG emissions compared to the PHEP ICS), (ii) reach environmental criteria, and (iii) produce high yield. The best candidates obtained through an ex ante assessment have been tested in a long-term field trial located in Grignon (France). Results were analyzed after one complete crop rotation. Crops were harvested at maturity with a farmer combine. An assessment of these ICSs was carried out with MASC®, a Multicriteria Assessment method of the Sustainability of Cropping systems.

At the opposite of what was expected, the GHG emissions were 10% higher in the L-GHG ICS than in the PHEP ICS. In the L-GHG ICS, C sequestration was lower than expected because both yields and cover crop biomasses were low. In addition GHG emissions were higher than projected because maize sowing required unexpected minimum tillage and many herbicides were used. The two ICSs met the environmental criteria in terms of crop diversity, N pollutions, pesticide use, and soil fertility. Yields almost reached the goals for these ICSs, with variations depending on the crops. Whatever the ICSs, cereal crop yields were systematically higher and field bean yields were frequently lower than expected. According to the multicriteria assessment, these two ICSs belong to different sustainability groups. The results will be discussed in order to analyze why the GHG targets have not been met, and to give assessment results in terms of sustainability.

134. Contribution of agroforestry to livelihoods and climate change mitigation in Western Kenya

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Agroforestry, the intentional integration of trees in crop and livestock farming systems, is an example of a climate-smart agricultural practice that offers opportunities for climate change mitigation and adaptation in vulnerable smallholder systems with low adaptive capacities. While other studies have identified carbon sequestration potential of agroforestry systems, the objective of this study was, firstly, to analyse farmers' practices and benefits regarding the use of trees on-farm and, secondly, to assess aboveground carbon stocks of the individual practices. The study was conducted in Western Kenya, and data were collected using household surveys, biomass assessments and tree inventories. Correlation analyses were applied to reveal linkages between on-farm carbon stocks and farm- and household characteristics. Results show that importance of on-farm trees is determined by the possibility of income generation and value for household consumption. Timber is considered the most important use of on-farm trees before firewood and construction material which both have a high value for household use. In the study area on average 4.23 ± 3.55 Mg C/ha are stored per farm. Total farm carbon stocks are determined by practices and species composition, but not by farm size. Farms with woodlots have significantly higher carbon stocks than farms without. Socio-economic factors such as off-farm income and household size have no influence on on-farm carbon stocks. The results suggest that gaining self-sufficiency in firewood is the most prominent co-benefit with on-farm carbon storage. The focus on exotic species for timber production, though, can lead to a loss of biodiversity and presents a considerable trade-off. Changes in local environmental conditions over very short distances significantly determine livelihood strategies and carbon stocks. This work was part of the Standard Assessment of Mitigation Potential and Livelihoods in Smallholder Systems (SAMPLES) Project.

135. Alternative water management minimizes greenhouse gas emissions from rice systems while maintaining yield

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There is increasing pressure on agricultural systems to reduce their environmental impact while maintaining crop productivity, especially given the global nature of many environmental consequences. Agriculture is responsible for a significant portion of anthropogenic greenhouse gas (GHG) emissions. Rice cultivation has a higher global warming potential (GWP) than other cereal crops, largely due to the high methane (CH_4) emissions associated with continuous flooding. Alternate wetting and drying (AWD) of fields has been shown to significantly reduce CH_4 emissions, but its effects on nitrous oxide (N_2O) emissions and rice yield have been more variable. In this study, the CH_4 and N_2O emissions, yield, water use, and N fertilizer responses were evaluated in California and Arkansas for conventional continuously flooded fields and different AWD management practices. In California AWD reduced CH_4 emissions by approximately 60 – 80%, while N_2O emissions accounted for less than 20% of the total GWP. As there was no difference in grain yields or N fertilizer response between AWD and conventional management practices, AWD reduced yield-scaled GWP by 60 – 75%. In Arkansas AWD significantly reduced CH_4 emissions while N_2O emissions remained low and thus reduced total GWP by 50 – 90%. While rice grain yields for two of the AWD treatments were similar to the conventional yield, the AWD treatment that allowed field to dry the most before re-flooding showed lower grain yields. All AWD treatments showed 20 – 60% lower water use than the conventional system. Overall, proper AWD management practices can significantly reduce GHG emissions, maintain rice grain yields at similar N application rates, and reduce water use.

136. Climate mitigation: trade-offs between agricultural product carbon footprints and land use intensity

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Potential trade-offs between agricultural product carbon footprints (PCFs) and land use intensity are illustrated using a case study comparing traditional, low-yielding maize production in Tanzania with an intensified, high-yielding production system. In our comparative analysis the majority of extensive plots had lower farm gate PCFs than the more intensive plots. The conclusion may therefore be that the extensive systems should be encouraged as a climate mitigation strategy. However, the extensive systems with their low yields exert a large pressure on land resources, thereby potentially causing leakage effects beyond the system boundary of the PCF calculation. A second indicator exploring this effect, land use (LU), was calculated as the area of land required to produce a unit of output. Due to the higher yields in the intensive system, LU was more favorable for these plots. The two indicators show that a trade-off exists between PCFs and LU in this case study. Then the potential climate impact of this trade-off is illustrated. It is assumed that increasing demands by Tanzania's growing population are not met by food imports but by a local expansion of the low-yielding systems into semi-natural land, causing land use change emissions. Under this scenario, the higher-yielding system has a significantly lower climate impact than the extensive system. We conclude that without consideration of LU and potential leakage effects, there is a risk that agricultural systems that have low PCFs but exert a large pressure on increasingly scarce land resources may be encouraged. This may lead to unintended effects including significant carbon emissions due to land conversion to agriculture. Other indirect impacts or trade-offs between mitigation and adaptation are also possible. This case study supports the climate smart agriculture approach of working at a larger spatial scale to address interactions between individual farms and maximise mitigation at the landscape scale.

137. Integrated fertiliser microdosing and organic manure to adapt to climate variability and change in Northern Benin

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In northern Benin, maize is the most important staple food, but its productivity is negatively affected by low inherent soil fertility, soil degradation, and by recurrent droughts exacerbated by climate variability and change. In this study we combined mineral fertilizer and organic manure to evaluate cropping adaptation options to climate variability in Northern Benin. A split-plot in a randomized complete block design was set up in farmers' fields during the 2014 growing season to assess the effects of planting date (early, normal and late planting), mineral fertilizer [no fertilizer; microdosing option 1 (2 g NPK15-15-15 per pocket at sowing); microdosing option 2 (4 g NPK15-15-15 per pocket at sowing) and recommended rate (200 kg NPK per ha at 15 days after sowing and 100 kg urea per ha at 45 days after sowing) and manure (no manure, transported manure at 3000 kg/ha and transported manure at 6000 kg/ha) on maize production. Overall, there were no significant differences in maize development or grain yield among the two levels of manure and among the two microdosing option and the recommended rate. Maize growth and grain yield were increased by increasing the amount of nutrients applied. Maize grain yields for the normal and early planting were similar for each fertilization rate, suggesting there is a wide planting window for successful establishment of crops in response to increased rainfall variability. Yield decrease of >50% was observed when planting was delayed by 4 weeks (late planting) regardless of the amount of fertilizer applied but is less marked when fertilizer microdosing technique and organic manure are combined. Soil nutrient management had an overriding effect on crop production, suggesting that although the quality of within-season rainfall is decreasing, integrated fertiliser microdosing and organic amendments can be an option for adaptation in rain-fed smallholder cropping systems.

138. The Global Yield Gap Atlas for targeting sustainable intensification options for smallholders in Sub-Saharan Africa

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Providing food and water security for a population expected to exceed 9 billion by 2050 while conserving natural resources requires achieving higher yields on every hectare of currently used arable land. This is especially relevant for sub-Saharan Africa (SSA), where food production is not keeping pace with population growth. While recognizing there are other aspects to food security than production alone (*e.g.* distribution, demand, diets, waste, governance, population), efficiently increasing production on existing farmland forms an essential component of the sustainable intensification paradigm, which is a cornerstone of climate smart agriculture, as increased resource use efficiency contributes to both adaptation and mitigation via effects on farm incomes and reduced emissions per unit product. In SSA 80% of the food is currently produced by smallholder farmers, and rural population is projected to increase while average farm size will decrease in most SSA countries. Therefore, smallholder farms must be part of the solution to local and global food security. However, smallholder production systems across SSA are extremely diverse in terms of agroecology (climate, soils) and socio-economic conditions. Characterizing this diversity at a high enough resolution is essential for better targeting research and policy interventions in the context of global food security. The Global Yield Gap Atlas project (GYGA, www.yieldgap.org) has developed methodologies and protocols and collected data for yield gap assessments with local to global relevance. A new global agro-climatic zonation scheme was developed, with zones homogeneous enough in terms of climate relevant for crop growth, not too small to prevent robust local data collection on climate, soils and cropping systems, and covering most important current cropping areas so yield gap assessments can be upscaled from local to regional and national level. In addition we make use of improved digital soil information available from the Africa Soil Information Service (AfSIS). The Atlas can be used for national food security assessments as well as to target agronomic research and/or policy interventions.

139. Impacts of agricultural diversity on self-sufficiency for forage, feeding costs and GHG emissions in dairy systems

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Farmers are confronted with dynamic and interrelated changes in the production context (*e.g.* climate change). There is a challenge in the identification of adaptations of livestock systems susceptible to strengthening their resilience to these contextual changes while reducing their GHG emissions. In the scientific literature, there is a consensus for proposing to increase agricultural diversity and thus, redundancy within the system. Yet most published articles on the topic are reviews integrating field- and herd-scale results at the farm scale without addressing threshold effects implied by scale changes. We studied the impacts of an increase in agricultural diversity on self-sufficiency for forage, animal feeding costs and GHG emissions in dairy systems. We simulated the impacts of different adaptations based on such an increase in 4 livestock systems located on a diagonal across France for a succession of 4 years typical of future conditions. Three types of adaptations were tested: a change in the ratio of the area mechanically harvested (vs. grazed) to the whole farm area (F1), a change in the crops and grasslands grown or in the distribution of the area between crops and/or grassland (F2) and a change in calving periods from one season to another for part of the dairy cows (F3). All simulated adaptations had a positive impact on self-sufficiency for forage compared to the current situation and they did not increase animal feeding costs. The highest impact (+33%) was obtained by combining the three adaptations. They also increase the resilience of livestock systems to two types of climate events (spring and summer drought). Then, we conducted surveys in 4 livestock systems that had implemented these adaptations to characterize the evolution pattern of their GHG emissions. The 4 livestock systems decreased their emissions per liter of milk produced but only the 2 systems that had increased their grassland area decreased their emissions per hectare.

140. Water resources transfers through southern African food trade: resource efficiency and climate adaptation

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The connections between climate and the water-food nexus are strong and economically significant in southern Africa, yet the role of observed climate variability as a driver of production fluctuations is poorly understood. In addition, as regional collaboration strengthens through the SADC (Southern Africa Development Community) and trade with other regions increases, it is important to understand both how climate variability affects productivity and how intra- and extra-regional trade can contribute to the region's capacity to deal with climate-related shocks. We use international food trade data (FAOSTAT) and a global hydrological model (H08) to quantify the water resources embedded in international food trade across southern Africa and with the rest of the world, from 1986-2011. We analyse the impacts of socio-economic, political and climatic changes on agricultural trade and embedded water resources during that period. In particular, the effects of climate variability on trade flows and crop yields are estimated, to provide insights on the potential of trade as a collaborative adaptation mechanism.

141. Municipal solid waste composts as organic inputs in vegetable gardening cropping systems in Mahajanga, Madagascar

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Peri-urban agriculture is rapidly expanding in developing countries. Cropping systems that concern generally high added-value crops such as vegetables are intensive, with large organic or mineral inputs. The towns produce also large amount of waste which have to be managed. Municipal solid waste (MSW) composting process reduces greenhouse gas emission comparatively to waste storage in landfills. However, uses of MSW compost in cropping systems have to be tested to assess their efficiency in plant production and the soil quality preservation.

Two experiments were carried out near Mahajanga in Madagascar on "vegetable leaves" cropping systems, the main vegetable production in the country. Two MSW composts were compared to conventional organic inputs: poultry manure (site 1) or pig manure (site 2). The first one was initially composed of waste coming from market rich in vegetables residues, and the second compost was initially composed of waste of wider origin as green waste and other organic products. The N dynamic and plant yields were measured during two 3 month cropping seasons. All treatments were repeated 4 times according to a complete randomized experimental design. To assess the N mineralization of organic inputs, experiments in each site were repeated with or without plant.

The results showed that the yields obtained with MSW compost are higher than those obtained with pig manure and urea and similar to that obtained with poultry manure. Monitoring levels of soil mineral N revealed a significant accumulation of mineral N under certain conditions. This indicated a possible source of environmental pollution by nitrates.

In conclusion, MSW compost was efficient as organic fertilizer in vegetable cropping systems in Mahajanga, Madagascar. Intensifying MSW management this way could contribute to the development of climate smart agriculture around developing countries' towns, provided that the total safety of these organic products is verified, even after their application in soils.

142. Evaluating the impact of rising fertilizer prices on crop yields

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Due to tensions on fossil energy and phosphorus markets, the sharp rise in fertilizer prices observed during the last decades is expected to persist in the future, putting into question production pathways relying heavily on crop intensification. To evaluate how, in this context, economic choices may alter crop yields, we first construct different fertilizer price scenarios up to 2050, based on an econometric relation with oil and gas prices, or on the continuation of recent trends. The resulting changes in fertilizer price range between +0.8% and +3.6% per year over the 2005-2050 period. Once developed, these scenarios are tested in a global land-use model incorporating an endogenous representation of the land-fertilizer substitution. In doing so, this paper shows that the crop yields in 2050 are reduced by 6%-13%, depending on the scenario, due to the supply-side response to rising fertilizer prices. To meet the demand for food and non-food products, the fall in crop yields implies a global increase in cropland area ranging from 100 to 240 Mha. The sensitivity of the results is finally tested with regard to assumptions on food consumption, change in potential yield and nutrient use efficiency.

143. Agent based model analysis on the impact of agricultural land-use change adaptation in semi-arid Ghana

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Climate Change is a serious challenge to the future development of Africa, particularly the drier regions. Sahel and tropical West Africa are hotspots of climate change, and no matter how strong mitigation strategies are, some level of climate change effects will be experienced. Agriculture in the semi-arid Ghana depends largely on rainfall and it is also the key source of livelihood. In semi-arid Ghana, farmers are already changing their agricultural land-use to adapt to the impact of changing climate and variability. Similarly, different policies have aimed at improving farm household resilience towards the impact of climate change. Furthermore, some of these policies may influence change in agricultural land-use. Hence adequate understanding of the implication of these policies in spatial and temporal manner is imperative. This study applied the Land Use Dynamic Simulator model (Vea-LUDAS) as the agent-based model (ABM) to investigate the impact of farm credit as an agricultural land-use change adaptation strategy on farm household livelihood and soil loss.
Land use data and general household characteristics were obtained from 186 surveyed households in the Vea catchment, Ghana. These households were categorized using principal component and K-mean cluster analyses, and two household types were identified. They differ according to their human, natural and financial assets. Relevant spatial data (*e.g.* land-use, topographic features, soil features, etc.) were generated from geographic information system. Determinants of crop choices of each household type were generated through logistic regression of crop choices using household characteristics (*e.g.* age of head, household size, dependency ratio) and plots characteristics (*e.g.* soil type, wetness index, elevation, upslope area, plot size proximity features). Key sub-models namely, crop choice, agricultural yield dynamic and soil loss sub-model were programmed in Netlogo 5.0.5. Using a process based decision approach, the household choice of maize adoption with respect to maize credit scenario (MCS) was simulated and assessed its impact on farm household livelihood and soil loss. The impact of MCS on farm household livelihood and soil loss was compared with the baseline scenario or business-as-usual (BS) for a twenty year simulation period.
From the simulation result, MCS influenced the conversion of some agricultural lands into maize cropland. The number of maize adopters increased from about 20 % to about 50 % and the area put under maize cultivation increased by about 200 %. Average annual aggregated crop yield was 6.3 % higher under MCS compared to BS while average annual income was 1.2 % higher under MCS compared to BS. Furthermore, average annual soil loss did not show statistical difference under baseline and maize credit scenario. This study shows that MCS is able to improve farm household livelihood in the face of changing climate. However, an encompassing policy strategy will boost crop production and household resilience to impact of climate change and variability in the semi-arid Ghana.

144. The gathering of Non-Timber Forest Products as adaptation strategy to climate change in the rural community of Niaguis

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In Senegal, unstable weather conditions since the 70s increasingly cause land degradation or impoverishment, declining groundwater levels, degrading natural ecosystems, with a considerable reduction of agricultural production and generated income. This affects both cash crops and food crops. Indeed, agriculture, mostly rainfed, is strongly affected by the effects of climate hazards. It faces enormous natural difficulties affecting its development. It is in this subsistence agriculture, weakened by climatic instability and degradation of natural resources, that people have to find coping strategies to survive.
Ziguinchor, one of Senegal's wetter regions, is mainly agricultural. Its main activity consists in family farming performed by small farmers who experience the damaging effects of climate variability (decreased duration of rainfall, soil salinization, poor soils, etc.) that challenges all the certainties of the peasants. Thus, to meet the different challenges that have significantly deteriorated living conditions, people develop coping strategies to increase household incomes. These take several forms:
- agricultural forms through crop diversification, choice of species with short term, the introduction of new species, installing stone bunds, plantation development;
- and / or non-agricultural forms in village resources such as forest resource gathering. It is in this context that the Non Timber Forest Products (NTFP) harvesting, activity previously considered as marginal, practiced by a very small number of women and children, develops.

The methodology adopted was to collect quantitative and qualitative data. It was structured as follows:
- population grid;
- conducting questionnaire surveys;
- achieving the interviews and focus groups guides;
- direct observations.

The data presented in this article are the result of the implementation of these approaches. The quantitative and qualitative information from the field were combined for proper analysis.
The research, based on data collected from NTFP producers, helped to see that the mining and processing of NTFP are organized into channels and involve several players, pickers to small retailers, through many intermediaries. The number of collectors has increased dramatically, with the participation of more and more men, because of the significant revenue generated by market sales. In addition to its interesting economic potential, NTFP harvesting also plays a very important role in the diet of rural populations. Indeed, they are an important food supplement, especially during the rainy season considered a lean season by rural population, but also during periods of scarcity.

145. Optimisation of the nitrogen fertilisation in the context of climate change

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With abbreviated return times of extreme events, management of nitrogen (N) will become even more a priority issue. The decision-making process of N application is complex because the N optimal rate varies spatially and temporally and the impact of a decision is delayed in time from its application. The objective of this paper is to develop a decision support system (DSS) to optimise N management in an ecosystem perspective, including crop production and environmental objectives.
Winter wheat response to N was analysed between 2008 and 2014 on Luvisols, in temperate climate (Belgium). The usual Belgian practice consists in applying 60-60-60kgN.ha^{-1} respectively at tiller, stem extension and flag-leaf stages. By using the STICS model, the effect of variable N rates on crop growth and N available for leaching (NAL) were computed. 300 stochastic weather time-series were derived from LARS-WG for actual and future climatic conditions. The farmer's marginal net revenues (MNR) were computed as function of N costs and wheat selling prices. For each climatic probability level, the ratio R=MNR/NAL was estimated in function of the N rates. To minimize the risks, the DSS considered the curve R=f(N) corresponding to the probability level of 75%. The best N rate was the maximum value of this curve.
Results indicated that, under actual conditions, the N rates applied at flag-leaf could, at least 3 years out of 4, be decreased by 10 to 30kgN.ha^{-1}. Under A1B scenarios, the optimal N practice could be decreased between 60-60-0kgN.ha^{-1} and 60-60-30kgN.ha^{-1}.

146. Climate change impacts on crops production and adaptive measures from farmers' perspective in North-East China

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The North-East region of China (NEC) comprises the provinces of Liaoning, Jilin and Heilongjiang and the eastern part of the Inner Mongolia Autonomous Region. The NEC is the most important national commodity grain production region, producing around one third of the national commodity grains each year, but is one of the region's most vulnerable to climate change. Moreover, by 2020 the region will be required to meet a planned additional one third increase in national food production. Temperatures have increased in NEC by 0.3-0.5°C per decade, which is a rate higher than the rest of China. Reduced rainfall will increase competition for water resources between agriculture and the environment. The impacts of climate change so far has seen less wheat and more rice and maize produced in the region and the widespread adoption of conservation tillage practices. Longer season cultivars have been adopted by the local farmers increasing yields, although new pests and diseases are emerging. In the short to medium term, the strategies of the past will enable some of the impacts of climate change to be ameliorated. Policies on water storage and allocation will become particularly important for both production agriculture and the health of river systems in the NEC. Allied strategies of reforestation and afforestation will assist in reducing the rate of desertification, and this requires careful land-use planning using data from a proposed inter-provincial network monitoring trends in the climate, ecology and environment.

147. Emissions mitigation by sustainable intensification in Brazilian livestock production

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Reduced global meat consumption coupled with improved production efficiency is increasingly advanced as part of a sustainable agricultural intensification agenda to reduce harmful external costs, particularly direct and indirect greenhouse gas emissions. We show that depending on spatial and temporal factors, reduced consumption may not offer the anticipated emission reductions. Ruminant livestock is specifically implicated as a major cause of agricultural externalities in terms of greenhouse gas (GHG) emissions: direct (CH_4 and N_2O) and indirect (CO_2 from land use change). However a counter-argument suggests that grass-fed beef systems can have significantly lower emissions when accounting for atmospheric CO_2 uptake by deep-root grasses promoting soil carbon storage. We analyse the sensitivity of total GHG emissions in response to demand variations. The analysis employs a bottom-up linear programming model that simulates beef production, subject to demand and pasture area scenarios. The model optimises resources allocation, including the adjustment of pasture intensification levels according to bioeconomic parameters and estimates GHG emissions - including changes in soil organic carbon stocks. Focusing on the Brazilian Cerrado, we develop scenarios that show emissions actually increasing as a result of reduced demand, which increases the likelihood of carbon release from degraded pastures. Our results show if demand is reduced by 10%, 20% or 30% relative to baseline projections by 2030, emissions increase by 4%, 7% and 12%, respectively. But if demand increases 10%, 20% or 30% by 2030, emissions decrease by 5%, 8% and 13%, respectively. Increasing production to meet demand provides an incentive for pasture intensification through restoration practices (combined pasture improvement and/or feedlot finishing), and the resulting emission reductions offset those from increased animal numbers. The findings are a caveat to calls for reduced meat consumption and are a potential model for the management of other savannahs.

Acknowledgments: we acknowledge funding from the EU FP7 project AnimalChange under the grant agreements no. 266018. Rafael Silva acknowledges CAPES Foundation for the scholarship no. 10180/13-3. Dominic Moran acknowledges funding from Scottish Government Rural and Environmental Science and Analytical Services division through ClimatexChange, (http://www.climatexchange.org.uk/).

L2.4 Breeding and protecting crops and livestock

148. Adaptation of tropical cattle breeds to their environment, in the perspective of climatic change

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Cattle breeds may be broadly divided between temperate taurine breeds, from European origins, African taurine breeds, and Indian zebu breeds, and various admixed populations. A little number of these breeds has a worldwide distribution, while many of them have evolved in restrained areas and remain at a local or a regional level. Tropical countries are rich of a wide diversity of original cattle breeds, whose characteristics remain mostly undescribed. These characteristics are the results of various forces, such as the genetic background of the ancestral populations, the influence of agroecological environment in which they have evolved, and the livestock keeper preferences and practices. Tropical cattle breeds have therefore developed specific attributes and functions, to adapt to a wide range of environmental constraints and production systems. Such characteristics are the ability to tolerate high ambient temperature, with a reduced effect on their production skills, resistance to internal or external parasites and infectious diseases, valorization of rough diets, tolerance to harsh conditions and ability to recuperate during more favorable seasons, and working ability. These characteristics may be in the future of great utility to face the deleterious effects of climate change. The physiological traits involved in these characteristics are complex and their genetic basis has not yet been unraveled. However some studies of selection signatures identification give some insights on the genetic background of some adaptation traits of local tropical cattle breeds that could be useful in the future to face the direct and indirect effects of climatic change on livestock production systems.

149. Genetic diversity of *Dactylis glomerata* in the response to temperature during germination

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Grasslands are one of the dominant forms of land use in the world. They are seen, together with forests, as important sinks for atmospheric CO_2 and fundamental ecosystems for long-term storage of carbon. *Dactylis glomerata* L. is one of major species growing in temperate grasslands worldwide. It is greatly appreciated for its high agricultural value. However, temperature is one of the major factors controlling seed germination and initial seedling growth, two processes which affect the genetic structure of perennial populations.
The objective of this work was to explore the genetic variability of ryegrass in response to temperature during germination. Four wild populations and two varieties of *D. glomerata*, preserved in the Genetic Resource Centre for forage crops in Lusignan, France, were put to germinate, in the dark, in chambers at constant temperature ranging from 5 to 40°C with 5°C increments. Maximum germination percentage, lag to start of germination and maximum germination velocity were estimated for each lot and temperature. Significant differences ($P<0.01$) were observed in the response to temperature between the lots. At least four groups can be distinguished. The form of the response curves seems related to the geographic origin of the populations. These results show that high genetic variability does exist in response to temperature during germination within the species *D. glomerata*. This variability could be exploited to breed new varieties adapted to the new environmental conditions induced by the global climate change.

150. Globally representative *C. arabica* variety trial site selection in a changing climate

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Coffea arabica cultivation, breeding, and thus testing takes places over multi-decadal time spans. This makes climate change a concern in production and also trial site selection. Local germplasm collections of *C. arabica* have a narrow genetic base and varieties are adapted to a narrow climatic range. A global exchange of plant material is a priority means to confront climatic changes.
Our objective was to support the selection of variety trial sites that represent significant agro-climatic zones of global coffee production currently and in the future. We first defined agro-climatic domains of coffee production by cluster analysis of a global database of geo-referenced production locations. Random Forest classification of climate data layers was used to model the spatial distribution of these domains under current and future conditions. For important Arabica coffee production regions, the most representative climate domains were identified. Evaluating modeling uncertainty across independent model runs and future scenarios allowed the identification of efficient trial sites.
An advantage of our approach is the easy communicability of results for stakeholder engagement. On a global scale, our characterization of coffee production is in line with previous studies on agro-climatic zoning for coffee. Locally however, some of the locations recommended, based on systematic analysis, appear unfeasible. Therefore, the results will have to be validated by local experts. Future research will investigate the fate of regions that under future conditions were classified as no longer suitable for *C. arabica*. We will use the method presented here to identify analogous climates under current conditions to explore the option of setting up trial sites that represent future conditions.

151. "ReColAd": Collaborative network on farm animal adaptation to environmental changes

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Climate change is one of the major issues of our era. Many direct (high temperature) and indirect (availability of feed resources, sanitary challenges) consequences are expected in the short and medium term on livestock, both in the South (Mediterranean and tropical areas) where climate constraints are already important and will worsen in the near future, and in the North where heat waves and drought are likely to become more and more frequent. Even though the nature and magnitude of the effects vary from one region to another, adaptation of animals and more generally farming systems to the effects of global warming is a challenge to which research actors from the North and the South must be dedicated. Because of the difficulty of this challenge, it is necessary that research actors from a large range of disciplines (*i.e.* genetics, physiology, epidemiology, agronomy, economy etc.) work to propose together efficient and innovative approaches to adapt animals and breeding systems to the effects of climate change. By creating a network for sharing practices, methods and data it will be possible to promote in a concerted and organized way efficient approaches to help animals and farming systems adapt to climate change. This will allow broadening the range of knowledge and discussion to encourage multidisciplinary approaches and to identify the most appropriate procedures to integrate data of heterogeneous nature in the light of climate change.

Funding: The ReColAd network is funded by INRA Metaprogramme ACCAF

152. Crop diversity as an adaptation strategy to climate change in West Africa

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In Sub-Saharan Africa, climate fluctuation is believed to increase and smallholder's rainfed agriculture will be particularly challenged. This region is a crop domestication and diversity center for local crops, among which fonio, pearl millet and sorghum. A large amount of crop diversity is maintained by family farmers. This diversity is a basic fuel to allow future adaptation.

In this presentation, we illustrate how this extraordinary genetic diversity mitigates the actual impacts of climate change in different crops. We will further analyze what biological mechanisms are involved (local adaptation, selection, gene flow…). We will illustrate the particular role of fonio (*Digitaria exilis*, Stapf), a neglected and underutilized crop, in Western Africa agro-ecosystems. Our presentation shows that crops and landraces diversities are key factors for agriculture adaptation, and consequently that this diversity should be managed and conserved to allow local adaptation of agriculture.

153. Genetic variability and phenotypic characterization of thermotolerance in rainbow trout

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In rainbow trout farming, temperature will be the most difficult consequence of climate change to handle. Selective breeding is a way to adapt trout to temperature evolution. The objectives of this work was to (i) investigate genetic variability of tolerance to chronic high or fluctuating temperatures and resistance to acute temperature stress (ii) assess correlations between both stresses (iii) characterize adaptive responses of genotypes with high/low tolerance to temperature through physiological, endocrine and behavior analysis.
In a first step, 3 chronic thermal conditions were applied to 10 isogenic lines of Rainbow trout: 12°C (L), 20 °C (H) and a changing one (C): 12°-20°C-12°C every day. Survival and growth were monitored during 7 weeks to assess acclimatization to chronic stress. Acute temperature stress was also applied at the end of the period. Survival was high and similar in all groups while growth was significantly lower in C and H groups. Significant genetic-temperature interactions were evidenced for growth *i.e.* acclimatization to chronic stress. Significant genetic variability was found for resistance to acute stress with significant genetic-temperature interactions. However some lines were found resistant or sensible whatever the rearing temperature. Finally, no significant correlation was found between responses to chronic stress and acute stress which will complicate introduction of such traits in breeding programs.
In a second step, 2 lines with contrasted responses to temperature were exposed for 5 weeks to similar thermal conditions to the first step, followed by an osmotic stress for 5 days. The maintenance of ionic homeostasis was significantly modified in H group, more particularly for one isogenic line. Further mRNA measurements are performing in gills. Others experiments will be realized to determine temperature effect on behavior (during/after chronic stress) and response of corticotropic axis.

This work was funded by INRA, Métaprogramme ACCAF

154. NGS for identifying wild-to-cultivated gene flow for African crops adaptation

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Negative effect of future climate changes on agriculture is a major concern for worldwide food security. Adapting local crops to future harsher conditions is one objective of sustainable development and breeding programs. This will be particularly challenging in Sub-Saharan Africa. To improve adaptability of crops and agrosystems, farmers are relying on agrobiodiversity. Although using genetic diversity from local varieties has proven to be an efficient strategy for improving crops adaptation, it is expected that wild relatives will carry adaptations to more extreme environmental stresses. Living in more extreme conditions and often presenting a larger diversity than cultivated crops, wild relatives represent an important and interesting reservoir of adaptations. Wild relatives have been used for crop improvement for resistance traits to biotic (pest, disease) or abiotic (drought, salinity, soil acidity) stresses in breeding programs. In traditional agrosystems, weedy types have been used when harsher conditions arise or to increase diversity of varieties. The availability of next generation sequencing (NGS) technologies opens the door to wide genomic information even for non-model plants. Genomes of wild populations can be used to identify genes and polymorphisms linked to adaptations to future climatic conditions. We will review the importance of wild-to-cultivated introgressions in local African crops and the new perspectives that NGS technologies allow to address.

Authors acknowledge Agropolis foundation for funding from Open Science call 2014.

155. Impact of pea genetic variability on the control of N_2O reduction by soil-microorganisms-plant systems

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Some Rhizobiaceae, such as *Bradyrhizobium japonicum* USDA110, MSDJ49 or *Sinorhizobium meliloti* strain 2011, have the capacity to reduce the greenhouse gas N_2O. They possess the nosZ gene coding for the nitrous oxide reductase enzyme. While from our knowledge the nosZ gene has not yet been observed in any isolated strain of *Rhizobium leguminosarum biovar viciae* (symbiot of pea), the aim of this study was to try to reveal this capacity by the use of different varietal genotypes of peas. Five pea genotypes (Frisson and Austin as reference cultivars, Frisson-sym 29 and Austin-sym 29 as hypernodulating mutants and P2 as a non-nodulating mutant of Frisson, all mutants deriving from ethyl methane sulfonate mutagenesis) plus a control (bare soil) were cultivated in a greenhouse (6 pots per genotypes, 3 plants per pot) on a soil known as unable to reduce N_2O. At beginning of seed filling, pots were incubated for 48 h in airtight chambers. The N_2O concentration in chambers was periodically analyzed using a GC (electron capture detector) to evaluate N_2O production/reduction rates. Whereas no change in N_2O concentration in chambers during incubation was observed on both the control and the system with Austin, a low increase of N_2O concentration was observed for the system with the non-nodulating P2 genotype, a low decrease was observed for some replicates of the systems with Frisson or Frisson-sym29 and a clear decrease was observed for all the replicates of the system involving the Austin-sym29 hypernodulating genotype. The pea Austin-sym29 genotype has probably enhanced the development of specific strains having the nosZ gene and able to reduce N_2O. This study suggests that pea breeding and its interactions with soil microbial activities could contribute to greenhouse gas mitigation strategies.

156. Using crop-climate models for designing climate-smart breeding strategies

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Crop breeding will likely play a critical role with regards to improving food security under future climates by reducing crop sensitivity to future environmental stresses, as well as increasing crop yield potential and improving crop quality traits. However, critical knowledge gaps remain as to whether or how climate model information and/or model-based projections of genotypic adaptation can be used to contribute to the development of breeding agendas. Here, we conduct analyses that demonstrate which types of and at which scales climate and crop model information is likely to be robust enough so as to guide breeding using maize in Africa as a case study. We define robust information whenever the projected change (signal) is two times larger than the uncertainty (noise) under future climates – we term this relationship the signal-to-noise ratio (SNR). We assess SNRs for a number of maize-specific indices: heat stress around flowering (HTS), crop duration (CD), lethal temperatures (LET), and drought stress (DS) during the 21st century, and determine the times at which the projected changes in the different indices are robust (SNR>2). We find that climate model information more robust at the mega-environment scale (the scale at which long-term maize breeding decisions are made) than at the grid-cell scale, as noise averages out at coarser spatial scales. Results show early (SNR>2 before 2030) signal emergence for CD in all mega-environments, and no signal emergence for LET, HTS, and DS. For LET we find that the threshold is unlikely to be exceeded (low signal) whereas for HTS and DS it is climate model variance that limits robustness (large noise). Some mega-environments (wet upper mid altitude, wet lower mid altitude, wet lowland and to some extent also dry lowland), however, have a clear rising signal for drought, even though it does not reach S/N>2. HTS also shows a rising signal in all MEs, but particularly in the dry areas (dry mid altitude and dry lowland). Our relatively simple analysis of climate indices and a literature review of recently published crop modelling studies indicate that model-based studies can provide information regarding lead times at which various processes become important under climate change. This information can in turn be used to assess and adjust breeding priorities as well as the timing of varietal releases. In addition, our findings suggest that genotypic adaptation studies should be targeted at scales at which information is robust, thus ensuring breeding decisions can be made despite uncertainties in simulating future climates and crops.

157. Genetics of tolerance of extra-early Quality Protein Maize inbreds under contrasting environments

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Drought and low soil nitrogen (N) constitute the most important abiotic stress factors limiting maize production in West and Central Africa. A study was conducted to screen extra-early white quality protein maize (QPM) inbred lines and hybrids for tolerance to low soil nitrogen and drought stress, study the genetics of tolerance of selected inbreds to stress, identify the best testers and heterotic groups of the QPM inbreds across stress and optimal conditions. A total of 24 extra-early QPM inbred lines were crossed using the North Carolina 2 mating design to generate 96 single cross hybrids. Two separate trials were carried out at four locations under drought, low nitrogen and optimal conditions in Nigeria, 2012-2013. These involved 96 extra-early white QPM inbred lines with four inbred checks which are drought and low-N tolerant as well as 96 extra-early white QPM hybrids derived from the 24 extra-early white QPM inbreds and four hybrid checks. General combining ability (GCA) effects were significantly greater than specific combining ability (SCA) effects for all measured traits under stress, optimal conditions and across environments indicating that additive genetic effects were more important in the 24 inbred lines. The inbred lines were classified into three heterotic groups based on the GCA effects of multiple traits of inbreds. Inbreds TZEEQI 7, TZEEQI 134 and TZEEQI 145 were identified as the best testers. Average grain yield reduction under stress was 44.4% and 48.7% for the inbreds and hybrids, respectively. Inbreds TZEEQI 7, TZEEQI 78, TZEEQI 111, TZEEQI 60, TZEEQI 61 and TZEEQI 137 were identified as stress (drought and low-N) tolerant and could be used to improve grain yield and protein quality of maize breeding programmes in WCA. The tolerant inbreds identified need to be more extensively evaluated to confirm their tolerance to the two stress categories.

158. Adaptation of alfalfa ecotypes to climate change

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The availability of forage resources in European Mediterranean areas, subject to cyclical droughts and changing climatic conditions (temperature increase of + 0.6C°/decade, evapotranspiration + 50 mm/decade), has become a major challenge for livestock farming. Following professional organizations seeking INRA and CIRAD's expertise to search for alfalfa ecotypes capable of adaptation, we have been investigating the diversity of behaviors of 100 alfalfa ecotypes from 26 countries according to climatic constraints for the last three years. Key assumptions related to the response diversity in terms of i) survival, ii) productivity, and iii) nutritive composition. Tests were carried out without inputs or irrigation. Ecotypes of three different environments were pre-selected from a previous project with a total of 65 industrial, 25 farm and 10 wild ecotypes. The results obtained depending on rainfall amounts – *i.e.* favorable in 2012 with > 30 mm/month, and unfavorable in 2013 and 2014 with < 30 mm/month during the plant growth period –, can help us make selections based on biomass and total nitrogen content. Under rainfall deficit conditions results show:

• A marked drop in the productivity of industrial ecotypes due to their sensitivity, the variation of the dry matter is, in 2012-2013: - 25% ± 0.024; in 2012-2014: - 62% ± 0.015; in 2013-2014: - 46% ± 0.044;

• Resilience of farm and wild ecotypes highlighting a more interesting genetic variability for selection purposes;

• Changes in the earliness/maturity of the various ecotypes, which revealed opportunities to improve animal feed production (grazing periods, cutting dates…);

• An opportunity to integrate some ecotypes in multi-specific mixtures.

159. Improvement of yield and related characters of temperate maize (Zea mays L.) under three water regimes

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Improvement of maize grain yield under water deficit is a global demand; hence, breeding tolerance in maize to such conditions is necessary. Studies were conducted at Dirab Experimental Research Station, Saudi Arabia, from 2009 to 2012 to select suitable lines for water deficit tolerance. Six maize inbreds were crossed in a half diallel method to obtain 15 F1 hybrids which in addition to two commercial varieties were evaluated under three water regimes using Randomized Complete Block Design (RCBD). Soil water deficit was created a week before tasselling and stopped before grain filling using Food and Agricultural Organization (FAO) evaporation pan as a guide, with water applied at 50, 70 and 90 inches of water levels in the evaporation pan to create E1, E2 and E3 environments respectively. Wide diversity among maize genotypes and highly significant genotype by environment (GxE) interaction was recorded. Water deficit reduced plant height, and grain yield and increased days to anthesis, days to silking and anthesis silking interval. Grain yield of F1 hybrids was higher than that of their parental lines, with P5xP6 given the highest value indicating the usefulness of these hybrids for improvement. Although mid-parent heterosis values were higher than that of better-parent (BPH) heterosis, both varied with level of water supply, however, and hybrids with KSU 8-33 (P3), KSU 4-58 (P4), KSU 6-47 (P5) and KSU 3-69 (P6) parental background showed highly significant heterosis for all the characters across the environments and could be considered for further improvement.

160. Breeding for sunflower hybrids adapted to climate change: the SUNRISE collaborative and multi-disciplinary project

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The world oilseed production will face an increasing demand in the next 30 years (edible oil, biodiesel, green chemistry). In the context of climate change, an increased variability is expected in the timing and amount of water available for crop production. For sunflower crop, yield losses of 10 to 30 % have been predicted at 2030 horizon in Europe. Because sunflower is a major oil crop and is often considered as drought-tolerant, it shall take an important role in tomorrow's eco-friendly cropping systems. During the past 10 years, genetic progress was lower than expected, which requires the sunflower community to re-invest current breeding resources and methodologies.
To reach high and stable yields across a wide range of environments, an unprecedented project of 8 years, named 'SUNRISE', is gathering 10 public and 7 private partners since 2012.
The project associates several approaches: (i) the sequencing and genotyping of the genetic diversity among cultivated and wild sunflowers, (ii) the development of appropriate and high-throughput phenotyping strategies to characterize the molecular, physiological and agronomical responses to variations of the abiotic environment, (iii) the discovery through genome-wide association, linkage mapping and genomic selection of the genetic factors involved in those responses, (iv) the integration of this genetic knowledge into a crop model (SUNFLO) to test in silico G by E interactions and design promising ideotypes in future environments, and finally (v) the evaluation of the outputs for the breeding sector and the transfer of knowledge to agriculture by economists of innovation.
This large and unique partnership between INRA laboratories and the world-leading sunflower seed industry will ensure that the knowledge, resources and methods developed in the frame of SUNRISE will be translated into products and varieties supporting the adaptation of agriculture to societal and ecological challenges.

This research is supported by ANR-11-BTBR-0005.

161. Climate change in tropical environment: what impact on agricultural pests and diseases? What crop protection strategies?

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Global travel, world trade and change in climate conditions increase the risks from pest and disease incursions and outbreaks in many agricultural systems, threatening food security. Because insects are poikilothermic organisms they are able to change their habits and status, extend their distribution and as a consequence create more crop damage and economic losses. In this context farmers and crop protection specialists are concerned, particularly in temperate regions where the impact of climate change is obvious and well described. For example in Europe, the list of newly introduced insects, diseases and weeds coming from the south is increasing every year. In the tropical world, the impact of climate change on pest and disease populations and their natural enemies is less obvious and more difficult to apprehend. Through different examples of tropical agrosystems, this paper shows the effect of climate change on some major pests and diseases such as the coffee leaf rust, the coffee berry borer, the sugarcane stemborers, the cotton bollworm, and discusses new crop protection solutions to cope with the situation of climate change. On the one hand, these solutions are based on biosecurity plans to prevent any new introduction, and on the other hand they are based on agroecological management, with a particular emphasis on conservation of natural enemies to increase biocontrol and minimize pest infestation and outbreaks.

162. Understanding the genetic diversity of Ethiopian oilseed Noug (*Guizotia abissinica*) for its improvement and conservation

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Noug (*Guizotia abyssinica*) is an oil-seed crop, indigenous to Ethiopia, where it is the major source of edible oil and holds significant promise for improving rural livelihoods. It is the second largest export oilseeds in Ethiopia. Noug, however, is neglected by agricultural scientists, and utilization of its genetic resources for its genetic enhancement and conservation is very limited. The aim of this study was to investigate noug genetic resources and understand its genetic diversity for its improvement and conservation efforts. Noug collections were made in the central, western and northern part of Ethiopia during the noug harvest seasons of 2007 and 2008. During 2010/11 cropping season, 100 accessions augmented with four checks were planted in four blocks, each containing 25 accessions with 0.3 m distance between two rows of the same accessions and 0.6m distance between plots of different accessions at two testing sites namely Holetta and Ginchi. The accessions were characterized for agro-morphological traits, and environmental data were collected using GIS tool. Correlations between traits and a non-metric multidimensional scaling (NMDS) analysis of the phenotypic data were conducted using statistical software package R v. 2.10.0. According to diversity analysis of phenotypic data, most traits showed considerable diversity within and among populations. The regression analysis revealed that the number of seeds per plant was positively correlated with the number of primary or secondary branches which in turn had significant positive correlation with each other and with number of heads. NMDS analysis showed that the variability of noug response across the two testing sites and precipitation was the most important environmental factor that drives noug phenotypic diversity. As conclusion, strong selection for more heads and seeds are likely to boost yield, and diversity is found more within population than between populations which implies the need of on-farm conservation.

163. Proteomics in the drive for climate smart livestock production

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The overriding objective of livestock production is to supply human populations with edible and palatable protein and is the same whether in the chain of muscle to meat, production of milk and dairy products, and in the growing sector of aquaculture for farming of salmon or shrimps. It is surprising, given the importance of this protein production, that proteomics, the most advanced analytical systems for identification and characterisation of proteins, has had relatively little application in livestock production. The potential for proteomic technologies has however been revealed and stimulated by development of a network of experts linking this advanced technology with animal and aquaculture scientists (COST Action in Farm Animal Proteomics). Proteomics has been shown to have wide application in these fields and will become of even greater importance in understanding and implementing responses to climate change. Examples of the use of proteome analysis are coming to the fore. The muscle proteins that are of importance to seasonal weight loss in sheep due to alternating wet and dry seasons have been recognised and shown to be breed rather than nutrition associated. Similarly, in relation to swine production, proteome differences in the muscle phenotypes of Landrace, Duroc, Meishan, and Casertana breeds have been linked to enzymes of energy metabolism providing a bridge between genetics, physiology and production. As infectious disease prevalence alters in the advance of climate change, proteomics offers a means of characterising active pathogens by peptide analysis and, with the recent advent of quantitative proteomics, will increasingly provide a means for multiplexed biomarker detection and diagnosis of infection by multivariate analysis, to provide molecular determinants of responses and adaptation to climatic alterations. In aquaculture, the effect on the seasonal alteration in sea temperature on seabream growth and nutrition has been examined, with changes in the serum proteome determined, while novel diagnostics for infectious disease of Atlantic salmon, also affected by sea temperature, have been characterised. While there is great potential for proteomics in climate smart livestock production, a hurdle that needs to be overcome is the limited protein annotation and gene ontology that is available for even the major terrestrial domestic animals of cattle, swine and chicken. To fully exploit recent scientific and technological advances in proteomics for animal science, an international approach is needed to increase the bioinformatics available for farmed species.

The support of COST Action FA1002 in Farm Animal Proteomics is gratefully acknowledged (www.cost-faproteomics.org)

164. Bridging landscape genomics and quantitative genetics for a regional adaptation of European grasslands to climate-change

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In next decades, European grasslands are likely to experience damages and subsequent production losses due to changing climate. However, the large ecotype diversity of grassland species could be used to recombine natural climatic adaptations and value for services to create improved populations adapted to the foreseen future regional climates. The 'GrassLandscape' project (01/2015 - 12/2017) intends to use an innovative methodological frame (landscape genomics) to screen the natural diversity of a grassland species (perennial ryegrass) in order to discover genetic variability involved in environmental adaptation, and more specifically in climatic adaptation. This approach is based on the combined use of methods correlating genomic polymorphisms and environmental variations at sites of origin of genotypes and tests of signature of selection. To implement this frame, a genotyping method based on massively parallel sequencing technology is currently applied to 550 populations of perennial ryegrass sampled across Europe, Northern Africa and Near East. Populations are furthermore phenotyped in fields and in controlled conditions. Association models between genomic polymorphisms and environmental variations will then be used to map the spatial distribution of genomic markers linked to adaptive diversity in present climatic conditions and to foresee possible shifts in the spatial range fitting these markers in the context of several climate change scenarios. Based on these results, we will define allelic profiles of perennial ryegrass expected to provide climatic adaptation at regional scale over Europe under the foreseen future climatic conditions. We will finally design a number of genetic pools mixing different natural populations that will be used to initiate breeding programmes aiming to deliver improved populations adapted to future regional climates.

Acknowledgement: The 'GrassLandscape' project has received funding from the FACCE-JPI ERA-NET+ 2014 call 'Climate Smart Agriculture'

165. Ecological niche of *R. fistulosa* in climate change context: what future for lowland rice production in West-Africa?

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Rhamphicarpa fistulosa is a hemiparasitic weed of lowland rice in the family of Orobanche. It was distributed in Tropical Africa and Australia. It could cause between 40 and 100% of grain yields losses. Few studies have been done on the parasite and currently, there is no way to control ecologically its damage. In this study we aim to explore the future distribution of *Rhamphicarpa fistulosa* in climate change context in further years and the future of lowland rice production in West African areas. To achieve this objective, *R. fistulosa* occurrence data in West African countries were collected. We use the model Miroc with 4 climate change scenarios to project in the future ecological niche of *R. fistulosa* in West Africa. Maxent and Arcgis software package were used to run the model and the elaboration of the different maps. Our results showed that *R.fistulosa* will colonize seriously new inland valleys areas and will be highly distributed in a context of these climate change scenarios in the future. Lowland rice production will also be seriously affected in all of these areas in West Africa. It will be difficult for the concerned West African countries to produce lowland rice in ecological agriculture. We urgently need to elaborate a way to control this pest in a context of climate change to improve lowland rice production in West Africa.

We acknowledge the Organization for Women in Science for the Developing World which supports financially this study. We also thank the scientists of the Laboratory of Applied Ecology in Benin for their contribution and help.

166. Effects of heat stress and sulfur restriction during seed filling on grain characteristics in rapeseed

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Background and aims

In the coming decades, increasing spring temperatures are expected to impact crop yield and grain quality. Therefore, in a context of developing low input systems, the effects of temperature and sulfur (S) nutrition in rapeseed, which is a high S demanding crop, should be jointly considered.

Materials and Methods

In this study, the effects of high temperature (HT) and low S supply (LS) and their interactions during seed filling were investigated on yield, grain quality (nitrogen (N) and S, seed storage proteins and fatty acids (FA) contents), and germination characteristics (pre-harvest sprouting, germination at sub and optimal temperatures and abnormal seedlings). Complementary measurements were made to further characterize seed characteristics related to germination (abscissic acid (ABA) and gibberellic acids (GA) contents) and to the seed storage capacity (soluble sugar contents, and conductivity).

Results

Both stresses decreased reproductive ramifications and seed numbers per plant. Seed weight was less affected because of compensatory effects since the seed number per plant also decreased. HT seeds had higher S and FA contents, and lower ω6:ω3 and S-poor:S-rich proteins ratios while LS-seeds exhibited reverse trends for S and FA contents and the S-poor:S-rich proteins ratio.

High rates of pre-harvest sprouting were observed for HT-seeds along with lower ABA/GA ratios. Germination time courses of seeds were increased for HT-seeds at sub and optimal temperatures and for LS-seeds at optimal temperatures only. High rates of abnormal seedlings confirm the negative effect of HT on germination and early growth. High conductivity, which is an indicator of poor seed storage capacity, was increased for HT-seeds regardless S supply. Consistently, the smaller ratio (raffinose + stachyose)/sucrose in HT-seeds also indicated low seed storage capacity.

Conclusion

This study highlighted contrasting effects of heat stress and S limitation for valuable grain quality characteristics. It opens perspectives to better use S fertilisation management under warming conditions during the reproductive phase.

This work is part of the CAQ40 (CAQ40: Climate chAnge and Quality of fruit grain and seeds in the next 40 years) project, which was funded by the metaprogram ACCAF 'Adaptation to Climate Change in Agriculture and Forest' by INRA.

167. Selection of families new of rice for their adaptability of lowland in West Africa

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Experiments were conducted at the research institution AfricaRice's Cotonou, specifically at Sowe (Glazoué) and Kpelebeme, to identify and select varieties or strains of rice resistant and/or adapted to the various major ecological constraints, especially on rainfed lowland rice. The study ran from June to December 2012.
The experimental device used for the achievement of the objective is the strength evaluation test with efficiency of inoculum in descending order. It is composed of two lines over 2.60 m, spaced 0.20 m between line and 0.20 m on line. Different experimental lines were the subject lines seedling interspecific and intraspecific taken at the third, sixth and seventh generation. It's the lines from *O. sativa* x *O. sativa*, *O. glaberrima* x *O. sativa*, *O. sativa* x interspecific, *O. glaberrima* x interspecific, interspecific x interspecific, interspecific x *O. sativa*. These lines, number 1056, including controls, are planted perpendicular to the infective band consisting of Bouaké 189, ITA 306 and TOX3055-10-1-1-1. The measured parameters focused mainly on two vegetative characteristics (tillering at 30 and 60 days after sowing), on the cycle sowing-heading (reproductive character) and height at maturity and those related to biotic stresses (leaf blast, dead hearts) and abiotic (drought, iron toxicity). The quantitative variables were measured on 10 plants.
For the evaluation of qualitative characters, descriptive rating scales were used. The principle of selection of the lines on the agro-morphological characters and biotic and abiotic stresses involved a selection first on the field and then a selection in the laboratory.
At the end of this study, it appears that the family of crossing IR64 x RAM 90 including IR86153-B1-282-B-B is one that combines a strong tillering (44 tillers) and early cycle (84 days after sowing) in Benin. While crossing IR64 x TOG5677 family is one that combines a strong tillering (43) and a cycle AEP (127) in Togo. However ARC46-29, from WAB638-1 x NERICA-L55, tolerates blast leaf (1), iron toxicity (3) and drought (3) and represents one which combines good tolerance to stresses and the correct settings (good cycle seedlings-heading and average tillering) as well at the bottom of the slope and minor riverbed. It therefore presents adaptability to the conditions of the two sites (lower slope and minor riverbed).

168. Evaluation of triticale genotypes for food and feed security in Egypt

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Worldwide, global food and feed demands have been projected to double in the 21st century, which will further increase the pressure on the use of land, water and nutrients. In Egypt, the government has adopted a strategy to overcome the wheat gap (40%): 1) to increase the productivity of wheat vertically and horizontally 2) increase the production of bread by mixing wheat flour with corn or triticale flour. Triticale is used as food material for human and feed for animals throughout the world. Forty triticale genotypes were evaluated for two years at the Experimental Farm of National Research Centre, Shalkan District, Kalubia Governorate. The results revealed that the genotypes significantly differed from each other in the studied characters. Regarding days to flowering and maturity, triticale lines flower after 72.5 to 95 days. Five triticale lines were earlier than others > 80 days, while only line no. 8 was the latest flowering line < 90 days. The other 34 lines flowered between 70 – 80 days. A similar trend was observed in days to 90% ripening character. The same earlier lines were the earliest in ripening and ranged between 132 – 137 for the lines 1, 37, 38, 39 and 40, while, the latest maturity one was line no. 8< 150 days. Other lines matured between 140 – 150 days. Grain yield significantly differed among genotypes, where two lines *i.e.*, (6 and 8) gave the highest grain yield < ≠ ton fed compared the others genotypes. The same superiority of lines no. 6 and 8 in grain yield was evident for both straw and biological yields than the other lines. Also, the lines no. 3, 4, 5, 7, 9, 10, 21 and 23 gave the best straw and biological yields/m^2, indicating that triticale lines could out-yield grain, straw and biological yields. Therefore, they could successfully be superior genotypes under Egyptian conditions.

Acknowledgment: This work was financially supported by National Research Centre, Cairo, Egypt.

169. Improving Bambara groundnut for global food security: MAGIC populations for ideotype development and genomic analysis

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Bambara groundnut (Vigna subterranea L. Verdc) has the potential to contribute to global food security and sustainable agriculture due to its climate resilience attributes, particularly drought tolerance. However, typical of most underutilised species, there are no improved varieties developed via controlled breeding programmes. Landraces selected by farmers remain the main source of planting materials. Genetic constraints and variety preferences of value chain actors are the two main interdependent areas that define and shape breeding objectives. In Bambara groundnut for both of these, the following have been identified as important breeding objectives; (1) grain yield (2) photoperiod responses and fertility issues, (3) nutritional composition, (4) testa colour, (5) crop phenology and (6) drought responses. Specifically on photoperiod sensitivity, we have characterized a number of landraces/genotypes in controlled environments of 16h and 12h photoperiod treatment and based on this, IITA-686 and Akpa-4 have been identified as less sensitive and extremely sensitive, respectively. A bi-parental population involving these two genotypes IITA-686 and Akpa-4 has been generated and also segregates for important agronomic traits. On the basis of seed-related traits, QTLs likely to reflect photoperiod requirement have been mapped. A number of F3 photoperiod insensitive genotypes have been selected from this segregating population to be sent to southern Italy for field evaluation. 'Second/next generation' breeding populations appear to meet the strategic breeding needs of generating multi-utility germplasm resources for genetic/genomic analysis at the same time generating novel recombinants/ideotypes for introduction, evaluation and selection within different ecosystems. Ten genotypes of Bambara groundnut with phenotypic, allelic, and geographical origin diversity having the potential to contribute to these six breeding objectives of the crop have been selected as founder lines to build 8 parental MAGIC populations. The first set of F1 hybrids have been generated and will be advanced to generate the 4-way crosses for MAGIC development.

170. Genetics in controlling small ruminant's internal nematodes infestation in the era of climate change

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Nematodes infestation is becoming more of a problem in current situation of climate change. The costs of internal parasite control and treatment are therefore potentially very high in grazing sheep. Faecal worm egg count (FEC) has been suggested as a suitable selection criterion for selection for resistance to nematode infestation in livestock. Genetic parameter for FEC and its relationships with traits of economic importance in woolled sheep were assessed in the current study, using data from Merino sheep from a selection experiment maintained at the Tygerhoek research farm. Data consisted of ~7 100 animals born between 1989 and 2010. Rectal faecal samples were taken from individual sheep at 13 to 16 months of age after drenching was withheld for at least 10 weeks, generally in July to September. Nematode eggs were counted using McMaster technique, with a sensitivity of 100 eggs per gram of wet faeces. The fixed effects of birth type, sex, birth year and sex x birth year interaction were included in the operational model for FEC. Only additive animal affected the data for FEC. Heritability of FEC ranged from 0.10 for untransformed FEC to 0.16 for Log (FEC + 100). The genetic correlation of FEC with clean fleece weight was unfavourable in absolute terms, but not significantly different from zero. The genetic relationships of Log (FEC + 100) with staple length (SL) fibre diameter (FD), birth weight (BW) and scrotal circumference (SC) were favourable. Selection for FEC is unlikely to result in unfavourable correlated responses to economically important traits in South African Merinos, with the exception of CFW. This implies that selection for resistance to nematodes will aid in production of robust animals that are resistant/resilient to nematodes infestation in the era of climate change

171. Climate change impact on incidence of mite (*Tetranychus urticae* Koch) infesting ladysfinger in sub-Himalayan India

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Ladysfinger (*Abelmoschus esculentus* L. Moench) is an annual vegetable crop grown in tropical and sub-tropical areas of the globe. In the sub-Himalayan region of north east India the crop is cultivated throughout the year from 9 to 45 Standard Meteorological Week (SMW) except winter months. The crop is susceptible to various insect and mite pests, of which red spider mite, *Tetranychus urticae* Koch, causes heavy damage. Analysis of pooled mean data for the two years during the ladysfinger growing period on mite infestation revealed that the pest was active throughout the growing period except 9-12 SMW *i.e.*, last week of February to second week of March. Pest population reached high (6.18 mites/leaf) during 23rd SMW (3rd week of May) and thereafter started decline with the onset of monsoon and heavy rainfall, After rainy season, again pest population increased and reached highest population (7.56/leaf) on the 42nd SMW (last week of September) when the average temperature, average relative humidity and weekly total rainfall were 28.650c, 76.55% and 23.80 mm. respectively. A sudden fall of population was found with the heavy rains (weekly total 201.95 mm) during monsoon in 25th SMW (last week of June). The incidence of mite population always remained higher on the upper canopy of the plant, (54.32% population) compared to the middle and lower canopy. This result implies that mites were most densely populated in the young and new leaves. Correlation between mite infestations with important weather parameters showed that population had non-significantly positive correlation (p=0.05) with temperature, maximum relative humidity and weekly total rainfall whereas significantly positive correlation with minimum and average relative humidity. The population of mite had a tendency to increase with the increase of relative humidity coupled with high temperature. This weather forecasting report is helpful to formulate sustainable control measure for harmful pest.

L2.5 Overcoming barriers: policies and institutional arrangements to support CSA

172. Cross-scale policy dynamics and climate smart agriculture

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Many developing countries have updated select sectoral policies to address climate change, have created specific climate change policies and programs of action, and/or have established multi-stakeholder forums or platforms for the further development of climate change policy. The ability of such policies and policymaking processes to create an enabling environment for the pursuit of climate smart agriculture, however, is substantially shaped by the social spaces in which they are formulated and implemented, as well as how they interact with each other in implementation. These social spaces include governmental policy structures and institutional linkages across scales and levels of organization, as well as their interaction with informal social institutions of rural society. This presentation presents analysis of empirical findings on cross-scale dynamics of governance and policy issues pertaining to climate smart agriculture in Ethiopia and Senegal. The national agricultural policy environments in both countries are analyzed in terms of drivers behind policy formulation – including, but not limited to, evolving scientific knowledge, dynamic international discourses, global political pressures and changing donor networks/priorities. We also examine ways in which multiple policies and social factors intersect and interact in the spaces of implementation at the sub-national level, with the policy environments at each site being examined from the "bottom-up" lens of pastoral/agropastoral livelihoods. Principles derived from these two case studies offer lessons for more effective engagement between national governments, donors, scientific research and development partners toward climate smart food systems through a deeper understanding of policy and governance processes that shape them.

173. Theory and criteria for improved understanding of Climate Smart Territories (CST)

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Climate Smart (CS) agriculture in a territorial approach is defined by various actors as a combination of mitigation, adaptation and food security. However, current techniques fall short in capturing information of institutional ability of transformation, productive transformation dynamics and social development capacity.
A territorial approach integrates social, environmental, economic, political and global dimensions, leading to an understanding of socio-geographical spaces where actors collaboratively and equitably manage ecosystem services to improve the welfare of the population, continuously optimizing land use, mitigation and adaptation to climate change.
How can we assess comparatively CS territories? While intending to assess the climate smartness of a territory, not only we are challenged with complex data such as adaptation, mitigation and food security of different interconnected livelihood systems, but also with understanding drivers affecting farmers' decisions and their social capacities.
In this paper we propose different approaches towards such assessment. One of them, the Syndromes of Global Change, allow to characterise different utilization, development and sink patterns and all their possible interactions and thus can be used to assess climate smartness. We tested the Syndromes approach and analyzed bio-economic scenarios in selected territories in Central America. The second approach parts from the community capitals framework, evaluating the assets of a territory in relation to basic needs, assets that create capacities, and assets needed for implementation. We discuss strengths and weaknesses of both approaches in assessing readiness of a territory for the implementation of CSA, based on the connectedness of actions in different territorial scales.

174. Scenario-guided policy development and investment for Climate Smart Agriculture in Cambodia

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The agricultural sector is considered highly sensitive to climate change. In Cambodia, that sector is a lead one that represents 33% of the annual GDP, with 85% of the labor force engaging in agriculture. More than ever the question of how to produce more with less is key to ensure sustainable development and green growth - national priorities in Cambodia. Relevant national policy frameworks and smart investments are needed. The CGIAR program on Climate Change, Agriculture and Food Security and its partners, the FAO EPIC program on Climate Smart Agriculture and UNEP WCMC, facilitated a process where regional stakeholders developed scenarios for three countries (Cambodia, Laos and Vietnam) which were quantified using agricultural economic models and combined with climate scenarios. The narratives explore key regional socio-economic and governance uncertainties for food security, environments and livelihoods under climate change up to 2050. These scenarios were then used to identify entry points for most the urgently needed actions to increase climate resilience, and testing the impacts of future investments under different conditions with decision-makers in Southeast Asia.

Less than a year after their development, a policy process led to an identification of priorities for the Climate Change Priorities Action Plan for Agriculture (CCPAP) of the Cambodian Ministry of Agriculture, Forestry and Fisheries 2014-2018. This plan also features capacity building for scenario-based strategic planning among government actors. We provide lessons learned from this scenario-guided policy process to illustrate the potential and challenges of using scenarios for climate-smart agriculture policy and investment.

175. Effects of the Jordanian rainfed barley-livestock producer perceptions and values on their adaptation to climate change

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Resource-dependent farmers in Jordan's drylands did not take advantage of low-cost technologies intended to help mitigate the effects of climate change (CC). Climate-related factors are insufficient drivers to motivate farmers to adopt and invest in climate-smart technologies and objective factors only partially explain their adaptive responses. Using a socio-cognitive approach and an ordered logit model, this study explores the influence of farmers' values, understanding and knowledge of CC, the associated risks and efficacy of available technologies, and perceived adaptive capacity on their responses to climate change. Results show that farmers are at distinctly different stages of understanding and adaptation, ranging from avoidant maladaptation to active engagement in adaptation where subjective factors influence their decision-making processes. Belief in CC, when it began, and its causes, affects motivation to adapt. Farmer perceptions of how weather patterns have evolved over the years and the role of climate-smart technologies are not consistent with that of scientists – possible explanations to the wide maladaptation. For instance, farmers have not fully understood the consequences of continuing unsustainable traditional tillage methods or the benefits of the zero tillage technology. Results also show that values can limit adaptation, as change does not make sense in some value systems. The distinct inter-generational values are particularly important where young farmers are more likely to sell land and move away from agriculture unless convinced that improved technologies can increase the profitability and sustainability of agriculture. The implications of these results is that policy makers and development practitioners have important roles in enhancing farmer knowledge and understanding of CC and the available technologies that can help in coping with it.

The author gratefully acknowledges the support of NCARE (Jordan), ICARDA and IFAD, in facilitating access to farmers, data and technical guidance.

176. Climate Smart Agriculture in the Northeast: assessing stakeholders' belief-action gaps and research/extension capacity

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Regional and local climate change action is increasingly important to achieve goals for increased adaptation and mitigation in the agricultural sector. Northeastern farmers are already experiencing the effects of increasing climate variability and change. However, several barriers to action exist. For agricultural stakeholders in the Northeast to adapt to climate change, their values, beliefs, goals, and social networks must be incorporated into adaptation strategies (Bartels, 2012). Although stakeholder assessments have been conducted in other regions of the U.S. (Arbuckle, 2013; Prokopy, 2014), no comprehensive studies exist for the Northeast. Given that Northeastern agriculture is dominated by smaller-scale, diversified operations and varied landscapes, assessing stakeholder views on climate change is particularly important. Evaluating gaps between belief and action must also be a component of these assessments, given the evidence that Northeasterners increasingly accept that climate change is occurring, even though the issue is not yet one they view as a priority for action (Allred and Chatrchyan, unpublished Empire State Poll data).
This paper begins to address the existing gaps in knowledge about Northeastern agricultural stakeholder views and climate actions. We assess the following through social science research: 1) regional progress in achieving implementation strategies based on state-by-state assessment reports; 2) applicability of stakeholder engagement literature from other U.S. regions for the Northeast context; and 3) capacity of land grant university research and extension programs to meet stakeholder needs. These preliminary findings will provide the basis for a comprehensive needs assessment that we plan to conduct. Cumulatively, this information will guide research agendas and plans to develop portfolios of diverse practices, new tools, and strong farmer-extension networks to increase resiliency on Northeastern farms.

177. Barriers to the adoption and diffusion of CSA technological innovations in Europe

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Climate Smart Agriculture (CSA) is one response to the challenges faced by agriculture due to climate change. As with other sustainability transitions, technological innovation is highlighted as playing a critical role, however, the adoption and diffusion of technological innovations in OECD countries is slow. The aim of this paper is to identify key socio-economic barriers, in terms of supply and demand, that inhibit the adoption and diffusion of CSA technological innovations in Europe. To achieve this aim, a theoretical framework is constructed based on a literature review of socio-economic barriers effecting adoption and diffusion. This framework is explored with data from semi-structured interviews (n = 30) with CSA technology providers and members of agricultural supply chains, such as farmers associations and consumer goods producers (the end-users of the technology). Data was collected on the barriers they experienced, with interviews conducted in the Netherlands, France, Switzerland and Italy. This data was thematically coded and categorised to identify key barriers. Preliminary results show that CSA technology providers experienced barriers including difficulties in demonstrating added value and climate impacts of their technologies; lack of knowledge of, and access to markets/users; high costs with return on investment (ROI) being too long; and policy and regulatory issues. CSA technology end-users highlighted low awareness of CSA; high costs and overly long ROI periods; lack of verified impacts; regulatory and policy issues; low awareness of, and demand for CSA; and the unequal distribution of costs and benefits across supply chains. The results demonstrate that barriers exist on both the demand (user) and supply (technology provider) sides. The paper provides recommendations for increasing the adoption and diffusion of CSA technological innovations, as well as implications for the CSA and innovation literatures.

Acknowledgement: Project supported by Climate KiC.

178. Necessity of clear concepts and convergence of discourse for a climate-smart agriculture (Costa Rica)

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Since the 80's, many environmentalist discourses were elaborated at the international level, either in the form of technical topics or in the form of vaster concepts like "sustainable development". Studying the applications and effects at the local level of these topics and concepts makes it possible to anticipate, design and apply the recent concept of Climate -Smart Agriculture.

In this poster, we aim firstly to put in perspective the CSA concept with standard technical topics (soil erosion, biodiversity loss, and chemical pollution) and concepts (sustainable agriculture) and secondly to identify the precautions to be taken so that the CSA concept gives concrete results at a local scale. We wonder which conditions are necessary so that a concept has effects on farmers' practices.

Costa Rica is a country where the State promotes environmental protection following the influence of international concepts; CSA is already present in some leader institutions (such as FAO and CATIE). The country, as many countries in Central America, is affected by extreme climatic conditions associated with global change. We conducted this research in one of Costa Rica's top coffee-producing areas (Los Santos within the Tarrazu area). We interviewed 112 farmers, 24 members of local institutions and used participant observation to have a greater understanding of the social processes that lead to changes of agricultural practices.

The findings illustrate that: (i) local actors formulate their environmentalist discourses according to other objectives (ii) farmers put in practice environmentalist discourses when they are convergent (iii) divergence of discourses opens the door to farmers' idiosyncrasy and induces instrumentalization, that is greenwashing.

Experience highlights the necessity to approach the Climate Smart Agriculture concept in a convergent manner in order to avoid instrumentalization and inefficiency on the field and to enable conditions for an agriculture ready to face climate change and to meet development goals.

179. A rights-based approach to realizing socially equitable development outcomes from climate smart agriculture

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Efforts to enhance adaptive capacity require practitioners to engage not only with the technical challenges of responding to climate change, but also with the social and political context that determines distribution of costs and benefits. We explore how the socio-political contexts shape the institutions that manage the development and use of climate smart adaptations in agricultural landscapes. Current institutional arrangements support an uneven distribution of costs and benefits from natural resource access and utilisation, setting the stage for future patterns of winners and losers.

To better understand the causes of exclusion and marginalisation, we draw on human rights principles and lessons from rights-based development practice. We use a novel qualitative analytical tool to illustrate how the capacity of member of communities in Timor-Leste is influenced by the formal and informal institutions and actors that structure opportunities and barriers to resource use, access and benefits derived from the implementation of adaptations to climate change.

In Timor-Leste we found different forms of discrimination in social norms, the distribution of state support, and access to formal justice, which persist despite legal reforms and, indeed, through state institutions that legitimise local systems of inequality. This rights-framing exposes the processes of marginalisation and exclusion that must be addressed alongside (or prior to) efforts to promote climate smart adaptations. Failure to do so will risk further entrenching existing vulnerabilities. At the same time, rooted as it is in practice, our approach helps identify concrete actions that can be taken in support of marginalised groups. The tool and empirical illustration suggest that policy approaches to climate smart adaptation need to be developed in accordance with, and in support of furthering, human rights principles if they are to identify and prioritise the interests of the most vulnerable.

180. Implications of alternative GHG emission metrics for emission trends and targets

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Agriculture emits a range of non-CO_2 greenhouse gases, most notably methane (CH_4) and nitrous oxide (N_2O). To compare emissions from different countries and sectors and evaluate the effectiveness of mitigation actions, emissions are generally aggregated and reported as "CO_2-equivalent" (CO_2-eq) emissions. This relies on a weighting or metric to translate the emission of a non-CO_2 gas into its CO_2-eq emission. The most common metric used for this purpose is the 100-year Global Warming Potential (GWP), but the scientific literature provides a range of alternative options. Some of those alternatives would imply very different weightings especially for the relatively short-lived gas CH_4 relative to that of N_2O and CO_2. The choice of the most appropriate metric depends on the policy objective. Here I evaluate the implications of a range of alternatives to the 100-year GWP for emission trends (both absolute and emissions intensity) as well as preferences between and effectiveness of mitigation options. I focus my analysis on implications for New Zealand, which has an unusual emissions profile for a developed country, with almost half of its national total emissions coming from agriculture (if the 100-year GWP is used to calculate CO_2-eq emissions); but I also compare and contrast results with those that may be derived for other countries and at the global level, based on FAO data for emissions and production. Key conclusions from this analysis are that the choice of metrics could have a major influence on the apparent importance of agricultural emissions and subsectors within agriculture, and on long-term trends and feasibility of mitigation targets, for emissions intensity but even more so for absolute emissions. A farm-level analysis for New Zealand suggests that the most preferable mitigation actions are less influenced by the choice of metric, but in some cases the choice of metric could determine whether a specific action actually results in an increase or decrease of CO_2-eq emissions.

181. Climate smart agriculture without climate smart spatial planning?

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Meteorological and climatological measurements of climatic change in Europe show that intense precipitation has become more severe and more frequent. Slovenia, a country situated at the junction of the Alps, the Mediterranean, the Pannonian Basin and the Dinaric Alps, is no exception. The risk of and vulnerability to floods have increased over many areas due to a range of climatic and non-climatic impacts, therefore the activities to implement prevention measures are in full impetus. However, in the evaluations of the damage caused by these extreme events and the objectives of prevention measures, the focus is given on urbanized, settled areas and infrastructure, while the (long-term) consequences on agricultural land are often neglected, regardless the fact that agricultural land (and agricultural production) face a twofold effect: direct devastation by flood water and limited production for the benefit of establishing the retention areas. Emerging land-use conflicts are hindering the flood adaptation process and reveal the results of shortsighted spatial-planning practices from the past.
The poster will present the study case of the capital Ljubljana and its rural surroundings, where highly intensive urbanization in the last few decades increased flood vulnerability of the city itself and the areas downstream. The analysis will show the immense increase of agricultural land affected by urbanization, floods and planned prevention measures. It will also present the complexity of emerging conflicts between national authorities, city authorities and (upstream and downstream) local communities, deriving from poorly-led participatory processes for obtaining the public and landowners' consent to implementation of the flood prevention measures.
This case study will clearly demonstrate that there cannot be Climate Smart Agriculture without Climate Smart Spatial Planning.

182. Forestry and agriculture in the climate change governance: Non-UNFCCC venues for enhancing action

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Deforestation is responsible for almost one quarter of global anthropogenic emissions. Agriculture is one of the main drivers of this deforestation. Currently, deforestation is being addressed within the United Nations Framework Convention on Climate Change (UNFCCC), through the Reducing Emissions from Deforestation and Forest Degradation in Developing countries (REDD+) discussions. REDD+ has positioned itself as a central element of the international climate change governance system and it is receiving large amounts of funding. The consideration of agriculture within the UNFCCC, however, has faced opposition, even though agriculture is closely linked to deforestation. As a reaction to this lack of progress, and as a way to enhance action on the ground, new and more inclusive initiatives outside the traditional intergovernmental mechanisms have been created. One of them is the recently launched Alliance on Climate Smart Agriculture (ACSA). However, it is also struggling with similar objections as those raised at the policy arenas. This paper analyses how a public-private initiative mobilized outside UNFCCC, such as the new ACSA, contributes to and interacts with the climate change governance system and could offer new venues for the integral consideration of forestry and agriculture in the context of climate change. It applies an analytical framework based on the literature on institutional interaction and interaction management, as well as framing theory.

183. Barriers to uptake of conservation agriculture in Malawi: multi-level analyses & development planning implications

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New multi-level analyses are presented assessing barriers to adoption of conservation agriculture practices (as the main form of climate-smart agriculture in southern Africa) across Malawi. Despite significant donor initiatives that have targeted conservation agriculture projects as a route to ensure climate-smart agricultural development in Malawi, uptake rates remain low nationally. This paper is based on studies from 3 levels: i.) national policy analysis, interviews and a multi-stakeholder workshop; ii.) District-level assessments of development plans and District Office and extension service support, and; iii) Community / household level studies in two regions (Dedza and Nsanje) that have gained significant donor support aimed at supporting climate smart agriculture initiatives. The National Conservation Agriculture workshop identified three areas requiring collaborative research and outlined routes for the empowerment of the National Conservation Agriculture Task Force in enabling advances in uptake and associated benefits in terms of agricultural development, climate adaptation and mitigation. District-level analyses highlight that whilst District Development Plans are now checked against climate change adaptation and mitigation criteria, capacity and knowledge limitations exist at this level, preventing the up-scaling from project interventions. Community-level assessments highlight the need for increased community participation at the project-design phase and identify a pressing requirement for climate-smart agriculture planning processes to better accommodate, and respond to, the differentiated needs of marginalised groups (*e.g.* poor, elderly, carers). We conclude by identifying good practices that can be used to design, plan and implement conservation agriculture projects such that the multiple benefits can be realised. We identify changes to multi-level policy and institutional arrangements required to facilitate greater adoption of conservation agriculture in Malawi, noting the vital importance of District-level institutions and extension service amendments as requiring capacity building and support to ensure climate-smart agriculture benefits are realised more widely.

184. Policies for climate-smart agriculture: contribution of agroforestry literature

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Since more than a decade, growing attention is paid to agroforestry systems (AFS) to address climate change, nowadays making AFS a promising option for climate-smart agriculture (CSA). To promote CSA, setting enabling institutions and accurate policy is still an issue. In particular, three dimensions are controversial in policy design: the degree of sectorial integration of climate change policies in agricultural policies, the governance mode (market, State, civil society), and the scaling of institutions. In this communication, we analyze how scholars involved in AFS research deal with policy issues in a perspective of adaptation and mitigation to climate, with an emphasis on the three dimensions above-mentioned. Through a bibliographic study based on Scopus database (Elsevier) inquiries, we selected a dataset of 66 peer reviewed references that specifically and significantly deals with cross cutting theme of AFS, public policies and climate change. We observed that a strong corpus of references (n=40) advocate for more policies promoting agroforestry for solving climate change related issues but are not clear on the policy options to consider. However, most of the authors tend to recommend more integrated policies including climate change within agricultural policies. Regarding governance modes, scholars tend to emphasize markets, State institutions and civil society separately, highlighting the role of the latter. Regarding scale, authors claim for consolidating grassroots experiences, favoring local scales responses to national or international scales responses. Using policy science recent development, we finally discuss the limits of current AFS literature regarding analysis of institutions. For further research we recommend going beyond the exclusive conception of governance modes by considering more complex hybridization processes and paying more attention to participation and legitimacy issues in analyzing existing and new policies for AFS and CSA.

185. Learning and sharing for action: experiences of Ghana climate change and food security platform

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The population of Ghana is currently 25 million plus. Correspondingly, there is demand pressure on existing food systems and the environment. The situation appears exacerbated by climate change and its variability is affecting smallholder farmers and households, which results in food and nutrition insecurity in Ghana and the West Africa sub-region in general. Information sharing at all levels, however, remains critical for building the adaptive capacities of food systems actors. Climate adaptation actions appear isolated, disjointed and uncoordinated for meaningful gains. There is limited vertical interaction between local level community actors, researchers and policy decision makers. Too little solutions are therefore being harnessed for combating the observed degrading climate change effects. The CCAFS West Africa programme, with its intermediate development outcomes of food security, adaptive capacity, policies and institutions among others, embarked on the innovative strategic approach of using national climate change agriculture and food security platforms in Ghana, Mali, Senegal, Niger and Burkina for these purposes. In Ghana, a participatory multi-stakeholder mobilisation for platform establishment was initiated in 2012. In 2013, the platform was formally launched with a political buy-in from three key government ministries, namely: Ministry of Environment Science Technology and Innovation, Ministry of Food and Agriculture and the Ministry of Trade and Industry. This presentation seeks to profile the Ghana platform with defined structure and governance system and thereby share its experiences as a hub for a top-down and bottom-up information sharing, creating linkage mechanisms and opportunities for farmers/community-research-policy decision makers on salient climate-smart agricultural matters. The platform gained national stature with more support by engaging stakeholders in the regional capitals other than Accra. Platform engagement of local people at traditional agricultural festivals served well for climate change sensitisation and dissemination of climate smart innovations at that level. Endorsement of a communiqué by members from the Ghana parliament in support of climate smart agricultural activities pursued on the platform was one of the high points for platform organisation and management.

186. Linking climate change adaptation and mitigation: Implications for Central America

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Central America has been identified as one of the most vulnerable regions in the world – the dramatic pace and scale of changes are posing new challenges for the region's policy makers. Unfortunately, most policy responses are still fragmented; adaptation initiatives have been sparse, while mitigation has focused largely on the large forest-frontiers of the region, disconnected from the large scale adaptation demands of the population-dense pacific areas.

Widespread environmental degradation accelerates and exacerbates the Central American isthmus´ severe vulnerability to climate change and variability. While risk management and climate change adaptation are priorities on the agenda for the revival of regional integration, and the new round of climate change negotiations leading up to the COP2015 has created new impetus for addressing the shared challenges faced in the region, the policy frameworks and interventions remain dispersed and contradictory. In this context, the Adaptation-based Mitigation (AbM) approach being developed in El Salvador that seeks to integrate and complement adaptation, mitigation and development objectives, shows promise and is particularly relevant to addressing the formidable challenges of ensuring climate smart agriculture, food security and increased resilience that are being wrestled with jointly by all the ministries of agriculture of the region in the framework of the Central American Dry Corridor (CSCA).

This article presents the findings from a study conducted by Foundation PRISMA that seeks to inform the design of policy frameworks and institutional arrangements favorable to promotion of processes of large-scale transformation of agricultural practices in order to restore degraded landscapes and strengthen the resilience and adaptive capacity of Central America's communities.

187. Social learning in support of CSA: getting to outcomes and impact

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There is mounting external pressure on research-for-development organisations to contribute more effectively to the achievement of development outcomes. The multidimensionality of development challenges is exacerbated by the additional uncertainties and complexities posed by climate change. Research has a crucial role to play, but it needs to be aligned with societal learning processes so that it is not only demand-led but also addresses the needs of its users effectively. We hypothesise that social learning can contribute in two ways: (1) by helping to produce smarter, more effective research-for-development institutions, and (2) by helping these institutions achieve more sustainable development outcomes. These different contributions require different approaches, and neither is straightforward to evaluate. For the first, institutional change, we present two largely positive examples from within our own organisations. For the second, we currently lack robust evidence that longer-term benefits of social learning outweigh undeniable costs. We describe the Climate Change and Social Learning Initiative (CCSL), one of whose aims is to develop a solid evidence base of the utility of social learning, using a common monitoring and evaluation framework applied across initiatives being undertaken by a range of different organisations. Several of these initiatives revolve around policy and governance processes that are designed to facilitate investment in, and the uptake of, climate-smart agricultural practices in several regions of the topics. Already we are seeing the need for much stronger linkages between natural and social sciences, for increased (and different kinds of) interactions between research-for-development practitioners and other stakeholders, and for new ways of monitoring and evaluating progress through time. These are major challenges. But syntheses of documented evidence are critical to help us understand the processes by which communities can enhance their food security and adaptive capacity, as well as the nature of the institutions that can help to make these things happen.

188. Policy instruments for Climate Smart Agriculture: toward a specific integrated analytical framework

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Climate Smart Agriculture (CSA) must face climate change (CC) issues together with other priorities for agriculture and rural landscapes. Although a diversity of possible CSA conducive instruments can be listed, the policy processes conditioning their emergence and successful implementation have not been thoroughly identified. In most countries, instruments already exist to foster environmentally friendly practices, such agro-environmental measures, but their specific attention to CC is still limited. Simultaneously, agricultural actions take part of more general CC national strategies but face difficulties in being adopted and implemented. This communication proposes an integrated framework to analyze policy processes for CSA. From a review of mitigation and adaptation experiences in Latin America, we first identify the specificity of CC challenges for agriculture, and the existing policies and instruments that are currently proposed to CSA. Then, we review the different policy analytical frameworks developed by cognitive approaches of policy process analysis (Multiple Stream Framework, Advocacy Coalition Framework), and by institutional economics literature (Path Dependency, Institutional Analysis and Development). We identify the adjustments required in the existing frameworks to usefully analyze processes towards CSA conducive policies, enabling to cope with some specific issues of CC such as: its multiscale dimension, high level of uncertainties, high role of expertise, low salience of problem, difficulties to frame, law institutionalization of protagonists.

189. Building local capacity in agricultural carbon projects in Kenya and Uganda through participatory action research

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This paper presents the results of a participatory action research project which engaged agriculture carbon project managers, farmers, community-based organizations (CBOs), non-governmental organizations (NGOs) and local governments in an effort to strengthen the role of local institutions in the management of the carbon projects and to increase their local benefits. The study projects are managed by NGOs Vi Agroforestry in Bungoma County, Kenya and ECOTRUST in Mbale, Manafwa and Bududa districts in Uganda. The projects differ in their carbon sequestration activities as well as their certification systems – Sustainable Agricultural Land Management (SALM) and Voluntary Carbon Standard (VCS) for Vi Agroforestry and tree planting and Plan Vivo for ECOTRUST. This work builds on a previous effort, in which action plans were developed by the carbon projects to strengthen local institutional capacity to manage the elements of the carbon projects.

The implemented activities focused on the roles of CBOs and farmer leaders, the participation of women within the projects, links to local policy and relevant government agencies, as well as partnership development with other NGOs. For both Vi Agroforestry and ECOTRUST, training manuals were developed as capacity building tools. The projects also implemented workshops and demonstration farm activities to support their action plans. Research tools were designed to evaluate the effectiveness of these activities as well as generate additional ideas for future work to continue progress on the objectives of the study. The tools include qualitative and quantitative surveys and scorecards, which assessed impact of the projects' activities on the targeted groups as well as on the project management organizations. Based on our findings, we will present recommendations for how these experiences can inform future climate-smart agriculture project development, policy and financing efforts.

Note: Data analysis will be completed in December; therefore, we are not yet able to summarize our findings.

190. What does it take to see transformative adaptation? Evidence from sub-Saharan Africa

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Throughout sub-Saharan Africa, men and women are already adapting to climate change. However, these changes are often small, incremental changes that modify existing practices, such as modifying planting dates or changing crop varieties (Twyman *et al.* 2014). Encouragingly, we do see some farmers taking up what we term transformative practices – practices that contribute to diversified livelihoods, aim to buffer the household against climate changes, increase assets, and have a longer-term time horizon, but also require investments of time, labor, or cash. Transformative adaptations are both technological and behavioral and may require an adjustment in how resources are allocated, changing priorities and norms (Kate, Travis, and Wilbanks 2012). These transformative adaptations face significant barriers, including uncertainty in climate changes, perceived costs, and institutional and behavioral barriers (Ibid). Using a dataset collected under the Climate Change, Agriculture, and Food Security Research Program of the CGIAR, this paper analyzes the social, behavioral, and institutional determinants of transformative adaptations in Kenya, Uganda, and Senegal and identifies differences between men and women in terms of developing and promoting adaptive capacity. This information will be important for practitioners and policymakers seeking to identify barriers and manage tradeoffs in adaptation options at individual and household levels, as well as ensuring that both men and women have the capacities and resources to adapt to long-run climate change.

191. Is technical information what policy makers need to take action on the climate change adaptation of smallholder farmers?

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The adaptation of smallholder farmers to climate change should be a priority in Central America and Mexico, due to their importance for the agriculture sector and due to the impacts that a changing climate may have on their already precarious living conditions. However, the paucity of information on smallholder vulnerability to climate change in this geographical area may be one of the barriers that prevent policymakers to implement adaptation plans for smallholder farmers. We conducted an online survey with over 100 policymakers from seven Central American countries and Mexico to test the hypothesis that the lack of information may be a barrier for policymakers to take action on climate change adaptation for smallholder farmers, as well as to identify the information needed to support them. Our results show that the lack of information is a very important barrier for policymakers to take action on adaptation for smallholder farmers, followed by the lack of institutional capacity and the lack of financial support from the government. Information identified as most important include maps on the impacts of climate change on water; of areas prone to flood, droughts and landslides; of the most vulnerable farmers; on the projected temperature and precipitation in agricultural areas; and on the impacts of climate change on crop and animal productivity. Although this information is identified as very important to support the implementation of adaptation plans for smallholder farmers, our results show that they are rarely used by policy makers, even when available. We will discuss why this may be the case and emphasize the need of not only generating this knowledge, but also making sure policymakers understand the information produced, so it may more likely be used in making strategic decisions to help smallholder farmers adapt to climate change.

192. Drip irrigation works: drip irrigation kits do not

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The distribution of drip irrigation kits in Least Developed Countries (LDCs) has been supported by NGOs and the Development community, not by the professional irrigation industry. This attempt to improve production and conserve resources has failed. Climate-smart Agriculture (CSA) requires that irrigation systems not only mitigate the deleterious impacts of traditional agricultural regimes and provide adaptive tools for environmental change but also improve agricultural production and profitability for all growers and, in particular, smallholder farmers. Agricultural production in LDCs is stagnant. The average (mean) value added of agriculture to GDP in LDCs from 2002-2011 was -11.7%. Between 2011 and 2100 the population of high-fertility countries is projected to triple, passing from 1.2 billion to 4.2 billion and, in that period, projections are that agricultural production needs to increase by 70% overall, and by 100% in LDCs. Agriculture consumes 42% of all arable land available while climate scientists posit that the planetary threshold for land cover conversion to cropland is 11.7%. This research posits that the distribution of drip irrigation kits needs to give way to a proven professional institutional paradigm for improving agricultural production within the context of CSA to meet the challenges in LDCs. This comparative research study examines the distribution of drip irrigation kits in Eastern Africa over the past ten years and compares the quality of product, its distribution model and the results obtained to the distribution of commercially produced drip irrigation system in Kenya. Longitudinal data for this research is derived from local, reliable sources and from literature. The results of the research infer that drip kits are of inferior quality and not professionally supported while the drip irrigation systems which are designed, distributed and supported by the professional irrigation institutions continue to function and produce higher yields and profitability.

193. Barriers to adaptation and mitigation to climate change in livestock farms of Africa, South America and Europe

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Livestock farming contributes to climate change but in turns it is also affected by a changing climate directly on animal performances or indirectly via feed resources availability in terms of quantity and quality. Numerous studies have analysed the diversity of barriers for farmers to adopt new technologies for climate change adaptation and mitigation. But these studies were generally conducted for specific contexts. As part of the AnimalChange European research project, this work focuses on assessing farm-scale barriers across 10 countries: Senegal, Burkina-Faso, Kenya, South Africa, Madagascar, Brazil, France, Scotland, Netherlands, and Ireland, encompassing for both low and high-input systems.
A generic questionnaire was designed and applied to 175 farms addressing three themes i) general data on the farmer, his farm and its environment, ii) farmer's perception on climate change, iii) likeliness for introducing management options and barriers assessment if the option is not likely to be adopted. Based on a multiple factorial analysis, we characterised the links between barriers and farm activities, pedo-climatic conditions, market access, information access, funding, and farmer's education.
This broad analysis provides an overview of technical, social and economic barriers across different regions and systems. The main barriers to adoption in the South countries are mainly represented by lack of information, funding, and education, whilst in the North, the most important barriers are access to land and labour. The results of this research could be used by policy makers to understand what poses barriers to adoption across different sites.