CLIMATE-SMART Agriculture 2015

Global Science Conference

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Le Corum, Montpellier France

Parallel Session L3

Towards Climate-smart Solutions

Wednesday, 18 March 2015

8:30–12:30

Content

ORAL PRESENTATIONS

PARALLEL SESSION L3.1 CLIMATE ADAPTATION AND MITIGATION SERVICES

KEYNOTE PRESENTATIONS

08:30 AgMIP Contributions to Climate-Smart Agriculture
Rosenzweig Cynthia[1,2]
[1]*NASA Goddard Institute for Space Studies, 2880 Broadway, New York, NY 10025, USA*
[2]*Center for Climate Systems Research, Columbia University, New York, NY 10025, USA*

09:00 Adaptation and mitigation services for climate smart agriculture
Moors Eddy, Groot Annemarie, Werners Saskia
Alterra-Wageningen UR, Wageningen, the Netherlands

CONTRIBUTED ORAL PRESENTATIONS

11:00 Public-private partnership for climate-smart irrigation initiative in Morocco: the experience of Souss Massa Region
Lahcen Kenny[1], Hafidi Brahim[2], El Faskaoui Mhamed[3], Rami Abdellatif[4], Akhmisse Laila[5], Chemaou Hasna[5]
[1]*IAV Hassan II, CHA / AGROTECH, Agadir, Morocco*
[2]*Conseil Régional du Souss Massa Draa, Agadir, Morocco*
[3]*Agence du Bassin Hydraulique du Souss Massa Draa, Agadir, Morocco*
[4]*Agrotech-SMD; Agadir, Morocco*
[5]*Fondation Credit Agricole du Maroc pour le Développement Durable, Rabat, Morocco*

11:15 DSS for monitoring agro-meteorological and crop conditions in India using remote sensing for agro-advisory services
Sehgal Vinay, Singh Malti, Verma Rakeshwar, Vashisth Ananta, Pathak Himanshu
Division of Agricultural Physics, Indian Agricultural Research Institute, New Delhi - 110012, India

11:30 Can citizen science accelerate climate adaptation by poor farming households?
van Etten Jacob[1], Alwang Jeffrey[2], Arnaud Elizabeth[3], Beza Eskender[4], Calderer Lluis[1], Crichton Rhiannon[3], Eitzinger Anton[5], van Duijvendijk Kees[6], Fadda Carlo[7], Fantahun Basazen[8], van de Gevel Jeske[7], Gotor Elisabetta[9], Kassahun Mengistu Dejene[10], Kaushik S.S.[11], Kidane Yosef G.[12], Mathur Prem[13], Mercado Leida[14], Mittra Sarika[13], Moeller Anne Marie[15], Mondal Ashis[16], Pė M. Enrico[17], Richter Susan[2], Rosas Juan Carlos[18], Singh R.K.[19], Solanki I.S.[20], Steinke Jonathan[1,21,] Van den Bergh Inge[22], Zimmerer Karl[23]
[1]*Bioversity International, Costa Rica Office, c/o CATIE 7170, Turrialba, Costa Rica*
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[13]Bioversity International, Asia, Pacific and Oceania Office, New Delhi, India
[14]CATIE - Tropical Agricultural Research and Higher Education Center, 7170, Turrialba, Costa Rica
[15]Humana People to People India, New Delhi-110070, India
[16]Action for Social Advancement, Bhopal, Madhya Pradesh-462016, India
[17]Scuola Superiore S. Anna, Piazza Martiri Della Libertà, 33, 56127 Pisa, Italy
[18]Zamorano Pan-American Agricultural School, Honduras
[19]NEFORD, Vishnupuri, Aliganj, Lucknow, India
[20].S. Pusa Bihar, Indian Agricultural Research Institute - IARI, New Delhi, India
[21]Humboldt-Universität, 10099 Berlin, Germany
[22]Bioversity International, Belgium Office, W. De Croylaan 42, 3001 Heverlee, Belgium
[23]Department of Geography, Penn State University, 16802, University Park, Pennsylvania, USA

11:45 An international intercomparison & benchmarking of crop and pasture models simulating GHG emissions and C sequestration

Ehrhardt Fiona[1], Soussana Jean-François[1], Grace Peter[2], Recous Sylvie[3], Snow Val4, Bellocchi Gianni[5], Beautrais Josef[6], Easter Mark[7], Liebig Mark[8], Smith Pete[9], Celso Aita[10], Bhatia Arti[11], Brilli Lorenzo[12], Conant Rich[7], Deligios Paola[13], Doltra Jordi[14], Farina Roberta[15], Fitton Nuala[9], Grant Brian[16], Harrison Matthew[17], Kirschbaum Miko[18], Klumpp Katja[5], Léonard Joël[19], Lieffering Mark[6], Martin Raphaël[5], Massad Raia Sylvia[20], Meier Elizabeth[21], Merbold Lutz[22], Moore Andrew[21], Mula Laura[13], Newton Paul[21], Pattey Elizabeth[16], Rees Bob[23], Sharp Joanna[24], Shcherback Iurii[2], Smith Ward[16], Topp Kairsty[23], Wu Lianhai[25], Zhang Wen[26]
[1]INRA, Paris, France
[2]Queensland University of Technology, Brisbane, Australia
[3]INRA, UMR FARE, Reims, France
[4]AgResearch, Lincoln Research Centre, Christchurch, New Zealand
[5]INRA, Grassland Ecosystem Research (UR874), Clermont Ferrand, France
[6]AgResearch Grasslands, Palmerston North, New Zealand
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[9]Institute of Biological and Environmental Sciences, University of Aberdeen, Scotland, United Kingdom
[10]Federal University of Santa Maria, Santa Maria, Brazil
[11]Indian Agricultural Research Institute, New Delhi, India
[12]University of Florence, DISPAA, Florence, Italy
[13]Desertification Research Centre, University of Sassari, Italy
[14]Cantabria Agricultural Research and Training Centre, Muriedas, Spain
[15]ARC-RPS, Research Centre for the Soil-Plant System, Roma, Italy
[16]Agriculture and Agri-Food Canada, Ottawa, Canada
[17]Tasmanian institute of Agriculture, Burnie, Australia
[18]Landcare Research, Palmerston North, New Zealand
[19]INRA, UPR 1158 AgroImpact, Laon, France
[20]INRA AgroParisTech UMR EGC, Thiverval-Grignon France
[21]CSIRO, Australia
[22]Swiss Federal Institute of Technology ETH Zurich, Zurich, Switzerland
[23]SRUC Edinburgh Campus, Scotland, United Kingdom

[24]The New Zealand Institute for Plant & Food Research, New Zealand
[25]Department of Sustainable Soil Science and Grassland System, Rothamsted Research, United Kingdom
[26]Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China

PARALLEL SESSION L3.2 CLIMATE-SMART CROPPING SYSTEMS

KEYNOTE PRESENTATIONS

08:30 Climate Smart Agriculture – adaptation or transformation

Obersteiner Michael[1], Leclère David[1], Havlík Petr[1], Fuss Sabine[2,1], Schmid Erwin [3], Mosnier Aline[1], Walsh Brian[1], Valin Hugo[1], Herrero Mario[4], Khabarov Nikolai[1]
[1]Ecosystem Services Management, International Institute of Applied System Analysis, Laxenburg, Austria
[2]Resources and International Trade Group, Mercator Research Institute on Global Commons and Climate Change, Berlin, Germany
[3]Institute for Sustainable Economic Development, University of Natural Resources and Life Sciences, Vienna, Austria
[4]Commonwealth Scientific and Industrial Research Organisation, 306 Carmody Road, 4067 Qld, Australia

09:00 Designing and assessing climate-smart cropping systems in temperate and tropical agriculture

Debaeke Philippe[1], Pellerin Sylvain[2], Scopel Eric[3]
[1]INRA, UMR AGIR, 31326 Castanet-Tolosan, France
[2]INRA, UMR ISPA, 33883 Villenave d'Ornon, France
[3]CIRAD, UR AIDA, 34398 Montpellier, France

CONTRIBUTED ORAL PRESENTATIONS

11:00 Phosphorus use efficiency in symbiotic N_2 fixation for coupling bio-geochemical cycles in agrosystems with legumes

Drevon Jean-Jacques[1], Amenc Laurie[1], Bargaz Adnane[2], Becquer Thierry[1], Blavet Didier[1], Gérard Frédéric[1], Domergue Odile[3], Lazali Mohamed[4], ZamanAllah Mainassara[5]
[1]INRA Ecologie Fonctionnelle & Biogéochimie des Sols & Agroécosystèmes, 1 Place Viala, F34060, Montpellier, France
[2]Swedish University of Agricultural Sciences, Department of Biosystems and Technology, PO Box 103, SE-230 53 Alnarp, Sweden
[3]Laboratoire des Symbioses Tropicales et Méditerranéennes, Campus International de Baillarguet, 34398 Montpellier Cedex 5, France
[4]Université de Khemis Miliana, Route Theniet El Had, Soufay 44225 Ain Defla, Algeria
[5]CIMMYT, Southern Africa Regional Office, Peg Mazowe Road MP163, Mt Pleasant, Harare, Zimbabwe

11:15 Conservation agriculture and agroecology practices to mitigate climatic variations in medium altitude in Madagascar

Penot Eric[1], Fèvre Valentin[2], Flodrops Patricia[2], Razafimahatratra Hanitriniaina Mamy[3]
[1]CIRAD UMR innovation, DP SPAD, DR CIRAD, BP 853, Anpandrianomby, 101 Antananarivo, Madagascar
[2]Agroparistech, DP SPAD, DR CIRAD, BP 853, Anpandrianomby, 101 Antananarivo, Madagascar
[3]FOFIFA, Apandrianomby, 101 Antananarivo, Madagascar

11:30 Agronomic and environmental benefits of climate-smart farming practices modeled for rice-based system in India

Kwon Hoyoung, de Pinto Alessandro, Haruna Akiko

Environment and Production Technology Division, International Food Policy Research Institute, 2033 K Street, NW, 20006-1002 Washington DC, USA

11:45 Smallholders' coffee and cocoa agroforestry systems; examples of climate-smart agriculture

Vaast Philippe[1], Harmand Jean-Michel[2], Somarriba Eduardo[3]

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[3]*CATIE, 7170, Cartago, Turrialba 30501, Costa Rica*

PARALLEL SESSION L3.3 CLIMATE-SMART LIVESTOCK

KEYNOTE PRESENTATIONS

08:30 Climate-smart livestock systems: lessons and future research

Herrero Mario[1], Thornton Philip K.[2], van Wijk Mark[3], Rigolot Cyrille[1,4], Havlik Petr[5], Henderson Benjamin[1], Ash Andrew[1] , Crimp Steven[1], Howden Stuart Mark[1]

[1]*Commonwealth Scientific and Industrial Research Organisation, Agriculture Flagship, Australia*

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[3]*International Livestock Research Institute, Nairobi, Kenya*

[4]*INRA, UMR 1273 Metafort, F-63122 Saint Genes Champanelle, France*

[5]*International Institute for Applied Systems Analysis, Laxenburg, Austria*

09:00 Livestock and climate change: combining mitigation and adaptation options and projecting sustainable futures

Soussana Jean-François[1] and the EC FP7 'AnimalChange' consortium (see www.animalchange.eu)

[1]*INRA, Paris, France*

CONTRIBUTED ORAL PRESENTATIONS

11:00 Differential climate change impacts on crop and grasslands and the relative livestock production systems competitiveness

Havlík Petr[1], Leclere David[1], Valin Hugo[1], Herrero Mario[2], Schmid Erwin[3], Obersteiner Michael[1]

[1]*International Institute for Applied Systems Analysis, Schlossplatz 1, A-2361 Laxenburg, Austria*

[2]*Commonwealth Scientific and Industrial Research Organisation 306 Carmody Road, St Lucia, 4067 QLD, Australia*

[3]*University of Natural Resources and Life Sciences, Feistmantelstraße 4, A-1180 Vienna, Austria*

11:15 Efficiency gains for enteric methane mitigation and productivity: contribution to CSA and investment opportunities.

Gerber Pierre[1], Opio Carolyn[1], Mottet Anne[1], Steinfeld Henning[1], Hatton Victoria[2], Clark Harry[2]

[1]*Food and Agriculture Organization of the United Nations, Rome, Italy*

[2]*New Zealand Agricultural Greenhouse Gas Research Centre, Palmerston North, New Zealand*

11:30 Variations in egg incubation temperature enable chicken acclimation through long-lasting changes in energy metabolism

Loyau Thomas[1], Métayer-Coustard Sonia[1], Berri Cécile[1], Mignon-Grasteau Sandrine[1], Hennequet-Antier Christelle[1], Praud Christophe[1], Duclos Michel J.[1], Tesseraud Sophie[1], Coustham Vincent[1], Nyuiadzi Dzidzo[1,2], David Sarah-Anne[1], Everaert Nadia[3,4], Siegel Paul B.[5], Yalçin Servet[6], Yahav Shlomo[7], Collin Anne[1]

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

[3]*KU Leuven, Department of Biosystems, B-3001 Leuven, Belgium*

[4]*University of Liège, Gembloux Agro-Bio Tech, Animal Science Unit, B-5030 Gembloux, Belgium*

[5]*Virginia Polytechnic Institute and State University, Department of Animal and Poultry Sciences, Blacksburg, Virginia 24061-0306, USA*

[6]*Ege University, Faculty of Agriculture, Department of Animal Science, 35100 Izmir, Turkey*

[7]*Institute of Animal Science, The Volcani Center, Bet Dagan P.O. Box 6, 50250, Israel*

11:45 Impact of feeding strategies on GHG emissions, income over feed cost and economic efficiency on milk production

Inamagua-Uyaguari Juan Pablo[1], Jenet Andreas[1], Wattiaux Michel[3], Guerra Leonardo[1], Vilchez Sergio[1], Chacón-Cascante Adriana[1], Posada Karla[1], Barrantes Luz[2], Casasola Francisco[1], Villanueva Cristobal[1], Leon Hector[4], Lapidus Daniel[5]

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[2]*Universidad de Costa Rica, Centro de Investigación en Economía Agrícola y Desarrollo Agroempresarial (CIEDA) 141-2400 Costa Rica*

[3]*University of Wisconsin-Madison, USA*

[4]*Cooperativa Dos Pinos; 179-4060 Alajuela, Costa Rica*

[5]*U.S. Department of Agriculture; 1400 Independence Ave., S.W.; Washington, DC 20250 USA*

PARALLEL SESSION L3.4 CLIMATE-SMART LANDSCAPES, WATERSHEDS AND TERRITORIES

KEYNOTE PRESENTATIONS

08:30 Climate Smart Territories; what are they and how do we evaluate progress towards this goal?

Beer John[1], Louman Bastiaan[1], Mercado Leida[1], Scherr Sara[2], Van Etten Jacob[3]

[1]*CATIE, Costa Rica*

[2]*EcoAgriculture Partners, USA*

[3]*Bioversity International*

09:00 Towards climate smart landscapes and watersheds

Oswald-Spring Úrsula

CRIM-UNAM, Mexico

CONTRIBUTED ORAL PRESENTATIONS

11:00 Prototyping climate-smart agricultural landscapes: a generic modelling framework and application in a tropical island

Blazy Jean-Marc[1], Chopin Pierre[1], Doré Thierry[2,3], Guindé Loïc[1], Paul Jacky[1], Sierra Jorge[1]

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[2]*AgroParisTech, UMR 211 Agronomie, F-78850 Thiverval-Grignon, France*

[3]INRA, UMR 211 Agronomie, F-78850 Thiverval-Grignon, France

11:15 Managing trade-offs in climate-smart landscapes: a global analysis at multiple levels

Locatelli Bruno[1], Pramova Emilia[2], Chazarin Florie[2], Fedele Giacomo[3]
[1]CIRAD-CIFOR, Montpellier 34098, France
[2]CIFOR, Av La Molina 1895, Lima 15024, Peru
[3]CIFOR, Jalan Cifor, Bogor 16000, Indonesia

11:30 Climate-smart landscapes: multifunctionality in practice

Minang Peter A., Van Noordwijk Meine, Duguma Lalisa A.
ICRAF, UN Avenue, Gigiri, P O Box 30677-00100, Nairobi, Kenya

11:45 A platform for landscape ecoefficiency monitoring and jurisdictional certification in the Amazon region

Ferreira Joice[1], Poccard-Chapuis René[2], Laurent François[3], Plassin Sophie[2], Thalês Marcelo[4], Moura Fabricia[4], Pimentel Gustavo[5], Piketty Marie-Gabrielle[6]
[1]Embrapa Amazonia Oriental, Belém - PA, 66095-100, Brazil
[2]UMR SELMET – CIRAD, Paragominas - PA, 68626-140, Brazil
[3]Université du Maine, Le Mans 72085, France
[4]Museu Paraense Emilio Goeldi, Belém - PA, 66095-100, Brazil
[5]Embrapa Amazonia Oriental, Belém - PA 66095-100, Brazil
[6]UR GREEN – CIRAD, Montpellier 34000, France

PARALLEL SESSION L3.5 INVESTMENT OPPORTUNITIES AND FUNDING INSTRUMENTS

KEYNOTE PRESENTATIONS

08:30 Delivering Climate Smart Agriculture: prospects from climate finance

Hedger Merylyn, Nakhooda Smita, Norman Marigold
Overseas Development Institute, London, United Kingdom

09:00 "What Can Fund Climate Smart Agriculture?"

Searchinger Timothy D.
Princeton University, USA

CONTRIBUTED ORAL PRESENTATIONS

11:00 How to deal with trade-offs? – A manual for policymakers

Ignaciuk Ada
OECD, 2 rue Andre Pascal, 75016 Paris, France

11:15 Exploring strategic management of agricultural systems to link mitigation and adaptation to climate change

Iglesias Ana, Sanchez Berta
Department of Agricultural Economics and Social Sciences, Universidad Politécnica de Madrid, Madrid, Spain

11:30 Nationally appropriate mitigation actions (NAMAs) for upscaling climate-smart agriculture practices

Avagyan Armine, Karttunen Kaisa, De Vit Caroline, Rioux Janie

Food and Agriculture Organisation of the United Nations (FAO), Viale delle Terme di Caracalla, 00153 Rome, Italy

11:45 A business approach to poverty reduction: weather index based insurance and climate smart agriculture

Greatrex Helen[1], Hansen James[1], Hellin Jon[2], Osgood Daniel Edward[1]

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[2]*International Maize and Wheat Improvement Center (CIMMYT), Apdo. Postal 6-641, Mexico, D.F. 06600, Mexico*

POSTER SESSION 3

L3.1 CLIMATE ADAPTATION AND MITIGATION SERVICES

1. Scaling up climate information services within climate smart agriculture

Jay Alexa[1], Tall Arame[2]

[1]*International Research Institute for Climate and Society, Earth Institute, Columbia University, 61 Route 9W, Palisades, NY 10964, USA*

[2]*International Food Policy Research Institute, 2033 K Street, NW Washington, DC 20006-1002, USA*

2. Upscaling climate smart agriculture for food security in the Sahel region

Bilgo Ablasse[1], Subsol Sébastien[1], Botoni Yaro Edwige[2], Sarr Benoit[1]

[1]*Centre Régional AGRHYMET, BP 11011 Niamey, Niger*

[2]*Secrétariat Exécutif du Comité permanent Inter-Etats de Lutte contre la Sécheresse au Sahel (CILSS), 03 BP 7049, Ouagadougou, Burkina Faso*

3. Index-based insurance for income stabilization for smallholder farms in Central Asia

Bobojonov Ihtiyor[1], Aw-Hassan Aden[2], Biradar Chandrashekar[2], Nurbekov Aziz[3]

[1]*Leibniz Institute of Agricultural Development in Transition Economies (IAMO), Germany*

[2]*ICARDA, Abdoun Al-Shamalie, Khalid Abu Dalbouh Str., Amman 11195, Jordan*

[3]*ICARD, Tashkent, Uzbekistan*

4. Preliminary results obtained in the CLIF Project on climate change impact on fungal pathosystems

Huber Laurent[1], Bancal Marie-Odile[1], Zurfluh Olivier[1], Huard Frédéric[2], Launay Marie[2], Andrivon Didier[3], Androdias Annabelle[3], Corbière Roselyne[3], Mariette Nicolas[3], Belaid Yosra[4], de Vallavieille-Pope Claude[4]

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[2]*INRA, US 1116 AGROCLIM, F-84914 Avignon, France*

[3]*INRA, UMR 1349 IGEPP, F-35653 Le Rheu, France*

[4]*INRA, UR 1290 Bioger, F-78850 Thiverval-Grignon, France*

5. Modelling greenhouse gas emission under extensive livestock production systems in Kalahari South Africa

Tesfamariam Eyob H.[1], Hassen Abubeker[2], Booyse Maruzaan[2], Hutchings Nicholas J.[3], Stienezen Marcia[4]

[1]Department of Plant Production and Soil Science, University of Pretoria, South Africa
[2]Department of Animal and Wild Life Sciences, University of Pretoria, South Africa
[3]Department of Agroecology - Climate and Water, Aarhus University, Denmark
[4]Wageningen UR Livestock Research, Wageningen, the Netherlands

6. Institutionalizing crop yield forecasting for early warning in Nepal

Gyawali Dhiraj Raj[1], Kanel Damodar[1], Burja Kurstin Vance[1], Arun Khatri-Chhetri[2]
[1]United Nations World Food Programme, Nepal Food Security Monitoring System (NeKSAP), Vulnerability Analysis and Mapping (VAM), Lalitpur, Nepal
[2]CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), International Water Management Institute, New Delhi, India

7. Analysis of extreme climate events and their impact on maize and wheat

Diriba Tadele Akeba[1], Debusho Legesse Kassa[1], Botai Joel [2], Hassen Abubeker [3]
[1]University of Pretoria, Department of Statistics, Private Bag X20, Hatfield, 0028 Pretoria, South Africa.
[2]University of Pretoria, Department of Geography, Geoinformatics and Meteorology, 0028 Pretoria, South Africa
[3]University of Pretoria, Department of Animal and Wildlife Sciences, 0028 Pretoria, South Africa

8. Farmer rice field adaptation technology for rice-wheat cropping system in Punjab, Pakistan under future changing climate

Ahmad Ashfaq[1], Wajid Aftab[1], Khaliq Tasneem[1], Habib-ur-Rehman M.[1], Rasul Fahd[1], Saeed Umer[1], Hussain Jamshad[1], Hoogenboom Gerrit[2]
[1]Agro-climatology Lab., Department of Agronomy, University of Agriculture, Faisalabad, 38040, Pakistan
[2]College of Agriculture, Human, and Natural Resources Sciences, Washington States University, Prosser, WA 99350-8694, USA

9. Are autonomous adaptation help to improve resilience of farmers? Insights from local scale analysis from South India

Dhanya Praveen, Ramachandran Andimuthu, Palanivelu Kandasamy
Centre for Climate Change and Adaptation Research, College of Engineering, Guindy Campus, Anna University, Sardar Patel Road, Chennai – 600 025, India

10. Developing web services to foster the adaptation of agriculture, forestry and water management to climate change

Bréda Nathalie[1], Caquet Thierry[2], Gascuel-Odoux Chantal[3], Soussana Jean-François[4]
[1]INRA, UMR 1137 INRA-Université de Lorraine "Forest Ecology and Ecophysiology-EEF", Route de la Forêt d'Amance, F-54280 Champenoux, France
[2]INRA, UAR 1275 Ecology of Forests, Grasslands and Freshwater Systems Division, Route de la Forêt d'Amance, F-54280 Champenoux, France
[3]INRA, UMR 1069 INRA-Agrocampus Ouest "Soil, Agro and hydroSystem-SAS", 65 rue de Saint-Brieuc, F-35042 Rennes Cedex, France
[4]INRA, Collège de Direction, 147 rue de l'Université, F-75338 Paris Cedex 07, France

11. Evaluation of GHGs, C stocks and yields from European cropping and pasture systems under two climate change scenarios

Carozzi Marco[1], Massad Raia Silvia[1], Klumpp Katja[2], Eza Ulrich[2], Shtiliyanova Anastasiya[2], Drouet Jean-Louis[1], Martin Raphaël[2]
[1]INRA, AgroParisTech, UMR 1091 Environnement et Grandes Cultures, 78850 Thiverval-Grignon, France
[2]INRA, UR 0874 UREP Unité de Recherche sur l'Ecosystème Prairial, 63100 Clermont-Ferrand, France

12. Food security and climate change: a vulnerability analysis of agricultural livelihoods in Central America

Imbach Pablo[1], Bouroncle Claudia[1], Läderach Peter[2], Medellin Claudia[1], Beatriz Rodríguez[2], Armando Martínez[2]

[1]*CATIE, Climate Change and Watersheds Program, CATIE 7170, Turrialba, Costa Rica*

[2]*CIAT, Decision and Policy Analysis Program, Cali, Colombia*

13. Impact of climate change on household income and poverty levels: empirical evidence from South Asia

Rahut Dil Bahadur[1], Aryal Jeetendra[2], Ali Akhter[3], Behera Bhagirath[4]

[1]*Program Manager, Socioeconomics Program, International Maize and Wheat Improvement Center (CIMMYT), 10Km. 45, Carretera Mex-Veracruz, El Batan, Mexico*

[2]*Agricultural Economist, Socioeconomics Program, CIMMYT, New Delhi, India*

[3]*Agricultural Economist, Socioeconomics Program, CIMMYT, Islamabad, Pakistan*

[4]*Department of Humanities and Social Sciences, Indian Institute of Technology Kharagpur, Kharagpur-721302, West Bengal, India*

14. Irrigated rice practices changes in the Senegal River Valley according to climate and constraints evolutions

Baldé Alpha Bocar[1], Muller Bertrand[1,2], Van Oort Pepijn[3], Ndiaye Ousmane[4], Stuerz Sabine[5], Sow Abdoulaye[1], Diack Salif[6], Ndour Maimouna[1], Dingkuhn Michael[7]

[1]*Africa Rice Center (AfricaRice), Saint-Louis, Senegal*

[2]*Centre de Coopération Internationale en Recherche Agronomique pour le développement (CIRAD)/AfricaRice, Saint-Louis, Senegal*

[3]*AfricaRice/Wageningen University, Wageningen, The Netherlands*

[4]*Agence Nationale de l'Aviation Civile et de la Météorologie (ANACIM), Dakar, Senegal*

[5]*Hohenheim University, Stuttgart, Germany*

[6]*Société d'aménagement et d'exploitation des terres du delta du fleuve Sénégal et des vallées du fleuve Sénégal et de la Falémé (SAED), Saint-Louis, Senegal*

[7]*CIRAD/International Rice Research Institute (IRRI), Los Banos, Philippines*

15. Towards high resolution adaptation strategies to climate variability and change

Neethling Etienne[1,2], Le Roux Renan[1], Barbeau Gérard[2], Quénol Hervé[1], Rouan Mathias[3], Tissot Cyril[3]

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[3]*GEOMER-CNRS, UMR 6554 LETG, Université de Bretagne Occidentale, 29280 Plouzané, France*

16. AgMIP's transdisciplinary approach to regional integrated assessment of climate impact, vulnerability & adaptation

Antle John[1], Valdivia Roberto[1], Boote Ken[2], Hatfield Jerry[3], Janssen Sander[4], Jones Jim[2], Porter Cheryl[2], Rosenzweig Cynthia[5], Ruane Alex[5], Thorburn Peter[6]

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[2]*University of Florida, USA*

[3]*US Department of Agriculture (USDA), USA*

[4]*Wageningen UR, the Netherlands*

[5]*NASA Goddard Institute for Space Studies, USA*

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17. Representative agricultural pathways for integrated assessment of climate change, vulnerability & adaptation impacts

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18. Trends in dry spell and extreme rainfall events and significance for alternative and sustainable agriculture in Malawi

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19. Analysing the quality and reconstructing daily weather data for crop growth simulation models

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20. Gender assessment of climate change adaptation strategies in south-western Nigeria

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21. Sensitivity analysis for climate change impacts, adaptation and mitigation projection with pasture models

Bellocchi Gianni[1], Ehrhardt Fiona[2], Soussana Jean-François[2], Conant Rich[3], Fitton Nuala[4], Harrison Matthew[5], Lieffering Mark[6], Minet Julien[7], Martin Raphaël[1], Moore Andrew[8], Myrgiotis Vasileios[9], Rolinski Susanne[10], Ruget Françoise[11], Snow Val[12], Wang Hong[13], Wu Lianhai[14]

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22. Biochar: an environment friendly approach to mitigate climate change

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23. Response of fine rice cultivars to various transplanting dates under climate change scenario of Pakistan

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24. Climate smart services: case studies in Senegal, Burkina, and Colombia

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25. Climate-smart cropping patterns on exposed coasts and near-coastal uplands, central Vietnam

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26. Adoption of climatic challenges mitigating strategies at farm level: empirical evidence from South Asia

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27. Can ecosystem-based adaptation help smallholder farmers adapt to climate change?

Harvey Celia[1], Alpizar Francisco[2], Avelino Jacques[3,4], Bautista Pavel[2], Cardenas Jose Mario[2], Donatti Camila[1], Rodríguez-Martínez Ruth[1], Rapidel Bruno[3], Saborio Milagro[2], Vignola Rafaelle[2], Viguera Barbara[2]

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28. ITK Vigne, a decision-support tool to adapt wine production to climate change, with or without irrigation

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29. QUICKScan: A decision support tool for a participatory exploration of land use mitigation and adaptation options

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30. Gender specific perceptions and adoption of the climate-smart Push-pull technology in eastern Africa

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31. Critical issues for the design and operation of business models for technological CSA innovations

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32. Building resilience to climate change: the role of robust methods

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33. Co-design of scenarios and adaptation strategies to climate change in the highlands of Madagascar

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34. Climate change adaptation in the dry zone of Honduras: learning by doing

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35. From plot to regional scale, spatial modelling of crop systems using interaction graphs

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36. Climate Smart Agriculture, mitigation and adaptation, agro biodiversity conservation in Georgia

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37. Sensor-aided conservation agriculture: climate smart nitrogen and weed management in maize-wheat system

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38. Climate Change from the lens of a smallholders and their landscapes

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39. Assessing the vulnerability of sorghum to changing climate conditions in West Africa semi-arid tropics

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40. Network of experiments to phenotype contrasted sorghum and to model its adaptability in West African environments

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41. e-Agro Climate Initiatives - Ghana

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42. Climate-smart, site-specific agriculture: reducing uncertainty on when, where and how to grow rice in Colombia

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43. Microclimate drives pests in complex agricultural landscapes: how to monitor and analyse fine-scale climate data?

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44. Enhancing women farmers' access to climate smart technologies through participatory approach in rice farming households

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45. Assessment of community based biodiversity management for adaptation to climate change in Kaski district, Nepal

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46. Degradation of forest and agricultural resources and adaptation strategies in Middle Casamance (Senegal)

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47. Climate change and adaptation strategies of households as threats to food security in rural Southwest Nigeria

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48. Analysis of the adaptive capacity of rural farm households to climate change risks In Nigeria

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L3.2 CLIMATE-SMART CROPPING SYSTEMS

49. Climate smart village model for climate change adaptation and mitigation: implications for smallholder farmers in Ghana

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50. Agro Climate Calendar, a simple methodology to identify local adaptation for farm objectives

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51. Drip system and climate change adaptation

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52. Comparison of methodological approaches for durum wheat in-field monitoring and early-yield prediction

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53. Increasing vegetable research investments in South Africa for climate-smart vegetable research

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54. Improving farmers' innovation capacity for climate-smart forest and agricultural practices in Bangladesh

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55. Finding niches for neglected crops in the semi-arid to better manage climate risk under smallholder farm conditions

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56. Reducing the use of nitrogen fertilizers: how and what potential impact on N2O emissions from French agriculture?

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57. Climate Smart agriculture: farmers' perception and practices in Nepal

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58. The FACCE-ERA-NET+ project Climate–CAFÉ: climate change adaptability of cropping and farming systems for Europe

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59. Climate smart agriculture: Towards a concerted definition of national priorities in Mali

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60. New crops for a new climate: understanding farmers' behavior towards sesame and cowpea crops in Sahel

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61. Climate change and rainfed agriculture: how to extend the campaign and improve the Burkinabe agricultural production?

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62. Evolution of the rainy season and peasant adaptation in the Northeast of Benin (West Africa)

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63. Fitting sweet potato into low input cropping systems within contrasting agro-ecologies of KwaZulu-Natal, South Africa

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64. Study of sequestration of soil organic carbon under conservation agriculture and choice of simulation model

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65. Integrated approaches to adaptation to climate change and food security in Maradi (Southern Niger)

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66. Can woody plants management provide soil amendments to enhance agroecosystem productivity and resilience in West Africa?

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67. Dynamic capacity of the adaptability of steppe sheep breeding systems in response to the challenge of climate change

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68. Do practices of Sahelian smallholder farmers impact native agroforestry shrubs functioning?

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69. STICS: a generic and robust soil-crop model for modelling agrosystems response in various climatic conditions

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70. A model assessment of the adaptation of Mediterranean agroforestry systems to climate change

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71. The effect of organic amendments and water pulses on GHG emissions from rice production systems using δ13C isotope

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72. Nurse plant effect on mycorrhizal soil infectivity and soil fertility restoration in Madagascar upland rice farming

Baohanta Rondro[1], Randriambanona Herizo[1], Andrianandrasana M. Doret[3], Razakatiana Adamson T.[3], Razananirina Jefferson[3], Rajaonarimamy Elinarindra[3], Ducousso Marc[2], Duponnois Robin[2], Ramanankierana Heriniaina[1]

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73. Extension of oil palm in altitude under global change in North Sumatra: ecophysiological responses and yield

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74. Impact of climate on major cereal crops production in Sokoto State, Nigeria

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75. Resource-conserving agriculture for restoring soil productivity and climate change mitigation in northern Ethiopia

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76. Millet (Pennisetum glaucum)-acacia association for sustainable improvements in agricultural productivity in Niger

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77. Collection of farming address climate changes in the department Kaolack / Senegal

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78. Mitigating methane emission in rice ecosystem by drip irrigation

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79. Eating more grain legumes and less meat promotes climate smart cropping systems

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80. Acacia catechu trees in rice fields: a climate smart traditional agricultural system of Northern Bangladesh

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81. Soil carbon sequestration under traditional management of smallholder's oil palm plantations in Sudano-Guinean context

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82. Impact of climatic variables on rice yield in Bangladesh: a spatio-temporal analysis

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L3.3 CLIMATE-SMART LIVESTOCK

83. Productivity and mitigation effects of alternative feeding practices in smallholder dairy farms in the north of Vietnam

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84. Building climate smart pastoralism in the Sahel: ways forward

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85. Climate and animal diseases: the case of 2009/2010 rift valley fever outbreaks in South Africa

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86. Cattle ranching in the Amazon: quantifying synergies between intensification, mitigation and profitability

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87. Potential multi-dimensional impacts and tradeoffs of improved livestock feeding scenarios in Babati, Tanzania

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88. Towards climate smart dairy cattle in Rwanda: mapping feed resource potential under climate and land use scenarios

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89. Protein supplementation improves saline water utilization in lambs

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90. An optimal live-weight gain in winter improves growing performance and reduces CH_4 in tropical beef cattle systems

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91. Global farm platforms for sustainable ruminant livestock production

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92. Climate change, livestock productivity and poverty: empirical evidence from south Asian countries

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93. Solutions for greenhouse gases mitigation in ruminant farming: how to favor their adoption?

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94. Perception of climate change and adaptation of herd conduct mode in Burkina Faso during rainy season

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95. Mini-livestock ranching – raising climate-smart insects for nutrition and livelihoods

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96. Evaluating animal mobility in relation to climate change mitigation: Combining models to face methodological challenges

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97. Substitution of maize silage with barley silage in dairy cow diet as mitigation strategy: effect on milk quality

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98. Towards climate smart livestock systems in Tanzania: assessing opportunities to meet the triple win

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99. Predicting effects of cattle growth promoting technologies on methane emissions using TAURUS ration formulation software

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100. Farm scale greenhouse gas budget; grazing is smart

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101. Effect of ambient temperature on lactating sows, a meta-analysis and modeling approach

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102. Greenhouse gas and ammonia emissions from ceramsite covered compared with uncovered during dairy slurry storage

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103. Grass-legume mixtures enhance nitrogen yield over a wide range of legume proportions and environmental conditions

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104. Classifying livestock systems for public policy guidance: the example of Colombia's livestock sector

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105. Influence of xylanase enzyme on in vitro methane production and rumen fermentation of tikiya (Eleocharis dulcis)

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106. The effect of sunflower oil and the phenolic essential oils on methane emission in dairy cattle

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107. Utilization of saline water by Barbarine lambs in the dry areas under climate change

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108. Impact of feeding and breeding interventions towards climate resilient dairying system in India

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L3.4 CLIMATE-SMART LANDSCAPES, WATERSHEDS AND TERRITORIES

109. Large-scale land restoration – creating the conditions for success

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110. Regional impacts of climate change and adaptation through crop systems spatial distribution: the VIGIE-MED project

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111. Interdisciplinary approach to climate change in an intensely-managed agricultural landscape in California, USA

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112. Building a shared representation of the landscape as a socio-ecological system and visualizing the challenges of CSA

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113. Climate-smart territory approach: for an effective address of Climate Smart Agriculture

Mendoza César, Bastiaan Louman, Villalobos Roger, Carrera Fernando, Watler William
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114. Landscape scale assessments for strategic targeting of climate smart agriculture practices in East Africa

Winowiecki Leigh[1], Vagen Tor-Gunnar[2], Laderach Peter[3], Twyman Jennifer[3], Eitzinger Anton[3], Mashisia Kelvin[1], Mwongera Caroline[1], Okolo Wendy[1], Rodriguez Beatriz[3]
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115. The FACCE-ERA-Net Plus project "Climate smart Agriculture on Organic Soils" (CAOS)

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116. The potential of fish as a climate smart adaptation and mitigation strategy

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117. Water uptake in deep soil layers by tropical eucalypt plantations: consequences for water resources under climate change

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118. Land use practices among pastoralists as potential climate smart options for dry land ecosystems.

Rapando Nancy Phoebe
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119. Spatial models of farms territories, policy instrument and climate change: application in Chorotega (Costa Rica)

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120. Landscape management to develop agroforestry in Central-Africa

Peltier Régis[1], Dubiez Emilien[1], Marquant Baptiste[2], Peroches Adrien[3], Diowo Simon[4], Yamba Yamba Timothée[4], Palou Madi Oumarou[5]
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121. Governance for climate smart landscapes: a case from Makueni County, Kenya

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122. A landscape approach to co-designing climate change adaptation and mitigation strategies with farming communities

Castella Jean-Christophe[1,2], Lienhard Pascal[1], Phimmasone Sisavath[3], Chaivanhna Soulikone[3], Khamxaykhay Chanthasone[3], Frank Enjalric[1]
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123. Adapting landscape mosaics within Mediterranean rainfed agrosystems for managing crop production, water & soil resources

Jacob Frédéric[1], Mekki Insaf[2], Chikhaoui Mohamed[3], Amami Hacib[2], Bahri Haithem[2], Bailly Jean-Stéphane[4], Ben Mechlia Nétij[5], Biarnès Anne[1], Bouaziz Ahmed[3], Chehata Nesrine[6], Colin François[7], Corvisy Alain[8], Coulouma Guillaume[9], El Amrani Mohamed[10], Fabre Jean-Christophe[9], Feurer Denis[1], Follain Stéphane[7], Gana Alia[11], Gary Christian[12], Gomez Cécile[1], Hérivaux Cécile[13], Huard Frédéric[14], Jaïez Zaineb[2], Khattabi

Abdelattif[15], Lagacherie Philippe[9], Le Bissonnais Yves[9], Lhomme Jean-Paul[1], Masmoudi Moncef[5], Montes Carlo[1], Moussa Roger[9], Moussadek Rached[16], Naimi Mustapha[3], Ouerghemmi Walid[1], Planchon Olivier[1], Prévot Laurent[9], Quénol Hervé[17], Rabotin Michaël[9], Raclot Damien[1], Rinaudo Jean-Daniel[13], Sabir Mohamed[15], Sannier Christophe[8], Vinatier Fabrice[9], Voltz Marc[9], Zairi Abdelaziz[2], Zitouna-Chebbi Rim[2]
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124. Watershed and biodiversity restoration in the Western highlands of Cameroon under climate change

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L3.5 INVESTMENT OPPORTUNITIES AND FUNDING INSTRUMENTS

125. Livestock farmers' investment toward climate-smart production: impact of an incentive program in Chorotega, Costa Rica

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126. 25 million African farming families by 2025: science-development partnerships for scaling climate-smart agriculture

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127. Microfinance and Climate Smart Agriculture: integrated farming system and social business

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128. The CLIFF Network: breaking knowledge barriers for climate change mitigation research in developing countries

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129. Adaptation strategies for floodplain agriculture in Amazonia

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130. Afforestation and the unemployment nexus in the West African forest reserves localities: case study of Nigeria

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ORAL PRESENTATIONS

Parallel session L3.1
Climate adaptation and mitigation services

Wednesday, 18 March 2015

8:30 – 12:30

ROOM SULLY 1

KEYNOTE PRESENTATIONS

08:30 AgMIP Contributions to Climate-Smart Agriculture

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The Agricultural Model Intercomparison and Improvement Project (AgMIP) is a major international effort linking the climate, crop, and economic modeling communities with cutting-edge information technology to produce improved crop and economic models and the next generation of climate impact projections for the agricultural sector. Currently, AgMIP has over 650 participants from more than 45 countries contributing their expertise to over 30 projects and activities.

Since 2010, AgMIP has engaged stakeholders and researchers to assess climate impacts on food security and plan for a more resilient future. AgMIP has built a cutting-edge assessment framework on both global and regional scales, which links climate, crops, livestock, and economics to help decision-makers better understand how climate change will reverberate through complex agricultural systems and markets.

The goals of AgMIP are to improve substantially the characterization of world food security due to climate change and to enhance adaptation capacity in both developing and developed countries. AgMIP initiatives include regional integrated assessments; global economic assessments and global crop modeling activities; data and tools to facilitate multi-model and multi-discipline assessments; and cross-cutting themes to help interpret agricultural model results for decision-making.

AgMIP's wheat, maize, rice, sugarcane, potato, livestock, and sorghum/millet teams were organized to test the robustness of crop model projections of climate impacts on agricultural production with a particular emphasis on intermodel uncertainty and validation against high-quality field data. Each crop model intercomparison and improvement study selected a number of high-quality field sites, which ranged from partial information (to mimic data available at most locations) to nearly complete information levels in order to gauge fundamental responses to temperature, rainfall, and CO_2 concentration changes.

AgMIP's Coordinated Climate-Crop Modeling Project (C3MP) aims to improve understanding of the impact of climate change on future agricultural production by utilizing site-calibrated crop models to coordinate projections of crop response under probabilistic climate change scenarios. Collaborations among crop modelers with expertise at specific modeling sites can provide improved estimates of how agricultural production will be impacted by climate change and can help assess how consistent these estimates are across climate and crop models. The results from C3MP will also contribute to wider assessments undertaken by AgMIP.

AgGRID provides a central organizing hub for a new generation of gridded crop modeling activities within AgMIP, including the Global Gridded Crop Model Intercomparison (GGCMI). The goal is to build a lasting community of GGCMI researchers that collaborate to perform coordinated global and regional high resolution impact assessments and model intercomparison studies. In turn, these improve GGCMI applications and understanding of climate impacts on global food production, as well as regional and temporal variations in these responses.

AgMIP's Global Economic Model Intercomparison Team provided the first comprehensive investigation of uncertainty in projections of future commodity prices, agricultural land use, and agricultural gross domestic product (GDP). Climate change is projected to exert upward pressure on agricultural prices, but with large uncertainty. Economies respond by eliminating poorly yielding areas (buffering overall yield declines), increasing agricultural land use, and reducing consumption compared to the reference case with no climate change. While these reduce some of the detrimental impacts of climate change, there is still potential for large negative economic effects. Price uncertainties on the global market arise largely from the economic models, with smaller contributions from crop and climate models, although these can be substantial on the regional scale.

The AgMIP IT team enables the compilation, archiving, and exchange of data and information for the AgMIP research community and stakeholders. The main objectives of the team are to develop an IT infrastructure for AgMIP projects that allows easy and secure access to shared data, models, and results of researchers in the AgMIP consortium, with both a short- and long-term perspective; facilitate the use of data by models and exchange of model results and the linking of models relevant for reproducible and repeatable applications; explore state-of-the-art information and communications technologies relevant to improve agricultural modeling with a long-term perspective, including web-based model executions and service-oriented architecture (bio-informatics); and to organize the online dissemination of AgMIP data and outputs.

On the regional scale, AgMIP enables decision-makers to have access to information that can be used to evaluate and prioritize climate change adaptation strategies for smallholder agricultural households. This information is based on rigorous new data and methods for climate impact and adaptation assessment on the local and regional scales relevant to decision-makers, and supported by regional research teams. These findings directly inform planning across a wide range of local, regional, national, and international stakeholders, many of whom have been involved via AgMIP's stakeholder-engagement process. Results have led to improved scientific capacity around the world.

Results from these initiatives contributed to the Intergovernmental Panel on Climate Change Fifth Assessment Report, provide important context for national and regional stakeholders interpreting climate change risks, further state-of-the-art global food security assessments and agricultural models, and deliver key inputs, such as commodity prices, into regional integrated assessments.

09:00 Adaptation and mitigation services for climate smart agriculture

Moors Eddy, Groot Annemarie, Werners Saskia

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Recently, there have been major improvements in forecasting climate variability and water availability at a seasonal timescale. This information is valuable for farmers and water managers but needs to be made locally relevant and communicated in the appropriate format. Digital information and communication systems are increasingly used to provide decision-support and facilitate adaptation, mitigation and food security. These information systems are promising in achieving (policy) impact because they: (i) provide real-time access to data for large numbers of people at low cost, (ii) personalise and contextualise information provision, (iii) empower users by facilitating collection and analyses of data (comparable to crowd sourcing, citizen science), (iv) catalyse new forms of dialogue, learning, network-building and accountability. It is time to learn from existing experience to guide ICT development that enable services that support climate smart agriculture.

The precise definition of adaptation and mitigation services is still under discussion. The earlier focus of climate services on meteorological data is slowly changing towards the inclusion of possible impacts, vulnerability and adaptation options. The term Climate Adaptation Services was introduced as being a stepwise approach supporting the assessment of vulnerability in a wider perspective and to include the design and appraisal of adaptation strategies in a multi-stakeholder setting. This change also implies that the information provided by these services besides bio-physical data more and more include socio-economic data. Because of the compulsory emission reporting to UNFCCC and the trade in emission certificates, mitigation services are further developed than adaptation services. In addition the public interest in sustainability stimulated retailers to publish carbon emissions and water use of their products. The latter supported the development and use of among others carbon and water footprint tools, such as the "Cool Farm Tool" (www.unilever.com/aboutus/supplier/sustainablesourcing/tools/index.aspx). At present combinations of adaptation and mitigation services are still rare. Many requests for Climate Services will be a two-way exchange: not only will climate information be provided to users, but users will influence the development of Climate Services and the underpinning research by defining their needs.

Numerous websites and portals offering either mitigation or adaptation services have been developed in recent years. Often these websites are focused towards the use by scientists or policymakers. For scientists, the access to consistent datasets of climate drivers is essential, while for policymakers impacts vulnerability and socio-economic information of possible strategies and measures is most relevant. Other users have other specific requirements.

Starting point of most adaptation and mitigation services is access to and consistency in datasets. In the last couple of years numerous websites and portals have materialized. This development created an overflow of information and confusion for users such as policy makers, also often caused by the use of different definitions for the same expressions. Leading to an outcry for "One stop shop", guided search facilities, call centres for personalised support and dynamical search systems. Recent initiatives such as the Copernicus climate change service (see www.copernicus.eu) will help in creating consistency and accessibility of datasets such as temperature increase, sea level rise, ice sheet melting, warming up of the ocean and climate indices *e.g.* based on records of temperature, precipitation, drought events for both the identified climate drivers and the expected climate impacts.

Whereas websites and portals have sprouted in Europe in particular, up to now few applications can be found in the developing world. The exponential growth in the presence and use of mobile phones, internet and computers in all countries suggests that conditions for innovations have improved. This has already transformed many societal domains and practices and achieved great policy impact. In agriculture, mobile phones now play an important role in financial transactions and credit systems. Yet, application in climate services is still been lagging behind.

However, still little is known about what information empowers actors to self-organise and support adaptive behaviour or stimulate reduction of GHG emission. In addition, it is largely unknown what technologies most effectively support adaptive management, *e.g.* in their capacity to facilitate decentralised and participatory collection, personalization and analyses of data.

The main question therefore is: What design choices in terms of combinations of content, technology and social-organisation promote self-organisation in adaptive water/crop management and how can this be linked with actions that support mitigation?

Climate change creates new trade-offs, opportunities and uncertainties for policy formulation and implementation between the water and food sectors. Incentives to implement mitigation measures may come from the retailers or by creating a carbon credit market. Adaptive management has been proposed as an approach to deal with the inherent uncertainties associated with forecasting future outcomes. Adaptive management aims to help organizations, managers, and other stakeholders respond to, and even take advantage of, unanticipated events. Resources need to be managed in an iterative, social learning process. In this way adaptive management will increase the ability of stakeholders to fashion timely responses in the face of new information, taking advantage of self-organisation.

The review of information before action is taken and monitoring of outcomes of management actions is a critical element of adaptive management. Learning and self-organisation is achieved by managing information about projected and observed system responses to management actions. ICT solutions offer unprecedented opportunities for information sharing and for linking science-based models with (participatory) input of data and broad access to users and citizens. Examples are flood warning and water management systems in the Netherlands, weather insurances for farmers, or interactive tools for climate scenarios. Farm field schools may be used to facilitate learning and self-organisation by empowering users to review information before action is taken and to monitor outcomes of management actions.

Thus ICT can be instrumental in improving decision-making and influencing patterns of behaviour enabling us to address the challenge to create mitigation and adaptation services that are able to deliver context specific information that is applicable at the scale of interest of the end user. Public funding that opens up data information in combination with private initiatives focusing on the specific needs of the end-users will give a boost to the development of these services, if the added value can be made clear to the farmer.

CONTRIBUTED ORAL PRESENTATIONS

11:00 Public-private partnership for climate-smart irrigation initiative in Morocco: the experience of Souss Massa Region

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Located in South-Est of Morocco, the Souss-Massa-Draa region produces more than 60% of citrus and vegetables exported by the country, thanks to the intensive cropping systems adopted in irrigated land. These systems, while generating higher yields and higher incomes, are known to require a huge amount of water, therefore a considerable pressure was put on water resources, leading to a serious water deficit situation caused by the irrational use of irrigation and a series of drought episodes. The situation by 2050 is likely to get worse as the climatic change models predict a 20% increase in evapotranspiration, 20% drop in rain and 3° to 5°C increase in temperature.

This critical situation has prompted Agrotech, as a regional NGO, along with the Regional Council of Souss-Massa-Draa, the Agency for Hydraulic Basin, the Regional Office of Agriculture, the Association of Citrus Producer and the Credit Agricole foundation for Sustainable Development to launch an innovative climate-smart irrigation program (CSIP) based on a computerized regional network of 31 agro-meteorological stations. Using this network, 420 farmers receive a daily SMS with the necessary climatic data needed to fix crops' needs in terms of water, taking into consideration the specific microclimatic conditions where their crops are localized. More than 6000 other users have also access to these data via the web. Launched in 2006, the program is currently covering 40.000 Ha of citrus and 12.000 Ha of vegetables. Farmers affiliated to the program have also been enrolled in several training sessions on Good Climate-Smart Irrigation Practices (GCSIP). As a result, citrus farmers are now able to save 2000 m^3/Ha/year of irrigation water, 21% of energy and a considerable amount of fertilizers. Given the success of this public-private partnership, new projects are under preparation aiming at boosting climatic change mitigation in horticulture using the same network of agro-meteorological stations.

11:15 DSS for monitoring agro-meteorological and crop conditions in India using remote sensing for agro-advisory services

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The paper describes design, development and application of a web-enabled decision support system (DSS) for real time crop monitoring at district level and making the information available to different stakeholders, to build resilience of agriculture to weather variability. The system uses multi-temporal remote sensing images received at our satellite ground station from different satellite constellations. Regular real-time satellite derived parameters of rainfall, day and night land surface temperature (LST), and crop vigour index of NDVI are generated for crop pixels and aggregated at district level. Using historical values, weekly anomaly indices of standardized precipitation index (SPI), Temperature Condition Index (TCI) and Crop Condition Index (CCI) are generated for each of the 579 districts of India. The historical and real-time basic parameters and anomaly indices are archived in a database and can be accessed through a public web portal http://creams.iari.res.in. The portal allows visualization of SPI, VCI and TCI as categorized maps for current period and over the crop season. Besides, for a selected district, it shows the temporal profile of parameters for current year and its comparison with that of previous year and long-term average in graphical and tabular format. The parameter database is kept updated with new real time data and the system is under use since 2013-14 season. As a pilot study, the information generated through the system has been extended to regularly generate agro-advisories for the farmers of National Capital Region by dovetailing it with weather forecast and involving expertise of subject matter specialists. The agro-advisory is disseminated to registered farmers through SMS service in English and local language. It is expected that such a system will help in managing the agricultural weather uncertainties at the level of decision-makers in federal and provincial government departments and also at farmer's level.

11:30 Can citizen science accelerate climate adaptation by poor farming households?

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Climate adaptation requires a constant search for locally appropriate solutions in agricultural systems characterized by high heterogeneity and relative data sparsity. This challenge outstrips the capacity of traditional science. Citizen science may offer a solution. It involves recruiting large numbers of volunteers to help in scientific tasks, including data collection, analysis and interpretation. Citizen science complements participatory methods used until now in the agricultural sciences because it requires less group organization and involves more information and communication technologies (crowdsourcing). The global expansion of mobile telephone coverage makes it possible to use this approach more widely.

In this presentation, we will report on our preliminary experiences in using a citizen science approach for climate adaptation in Asia, Africa and Latin America. Our preliminary results show that: (1) "triadic" comparisons between different technologies is a simple and effective way to evaluate adaptation options, (2) interviews by mobile phone are feasible and can reduce costs of field work and (3) employment of small weather sensors by poor farmers in citizen science schemes is feasible but requires more R&D.

These preliminary findings feed into a multi-institutional initiative on citizen science for climate adaptation that will start in 2015 and is led by Bioversity International. The initiative will involve the systematic testing of different citizen science methods including a comparison with other participatory methods using a randomized control trial. We will specifically investigate behavioural and cognitive aspects (motivation, affective engagement, decision making), social and economic aspects (diffusion of adaptation options, gender and social inclusion, cost-benefit analysis). Based on the results of this research, we will be training a large number of professionals in applying citizen science methods for climate adaptation.

11:45 An international intercomparison & benchmarking of crop and pasture models simulating GHG emissions and C sequestration

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The development of climate mitigation services partly depends on our ability to simulate, with confidence, agricultural production and greenhouse gas (GHG) emissions so as to understand the effectiveness of the mitigation approach on both gas emissions and food production. The Soil C-N Group of the Global Research Alliance (GRA) on GHG has initiated an international model benchmarking and inter-comparison that will assess GHG balance and soil C sequestration of arable crops and grasslands as affected by agricultural practices. The inter-comparison arises from collaborations between GRA, AgMIP and four FACCE-JPI projects to lead to the largest exercise in this domain. An initial stock take has been conducted, resulting in the selection of datasets from five grasslands and five crop sites worldwide. A total of 28 models used in 11

countries for the prediction of GHG emissions in crop and grassland systems are contributing, ranging from process-oriented models to simpler models. The study has been set up with five successive steps that gradually release information to the modeling groups ranging from fully-blind application of the models to complete availability of the experimental measurements. Model simulations are compared to experimental measurements for crop yield and grassland dry-matter production, N_2O emissions, soil C stocks and net CO_2 exchanges. The precision and accuracy of the predictions are evaluated at each step of the inter-comparison with statistical methods, facilitating quantification of projection uncertainties. Results from the first step on N_2O emissions with no prior information show variability between model predictions for any site and that model error tends to be conserved across sites. Moreover, the frequency distribution of N_2O emissions already provides an understanding of model functioning in terms of N_2O peak prediction. Further steps will allow for improved site-specific prediction and, as a final step, will expose the measured GHG emissions for model improvement.

Parallel session L3.2
Climate-smart cropping systems

Wednesday, 18 March 2015

8:30 – 12:30

ROOM SULLY 2

KEYNOTE PRESENTATIONS

08:30 Climate Smart Agriculture – adaptation or transformation

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Climate change is associated with the large-scale disasters of the past few years – such as the appearance of previously unknown breadbasket failures in Australia, massive invasion of new pests in Brazil, unusually extensive flooding in large parts of Europe, devastating fires in Australia and violent ice storms in Canada – and has brought home to many governments around the world the realisation that something new is happening. There are still endless debates if these system changes are of gradual nature or whether our food system is at a threshold triggering a major regime shift. Such mega-risks associated with climate change in the agricultural sector have the potential for inflicting considerable damage on the vital systems upon which our societies and economies depend, and create serious difficulties for traditional risk management in the sector. Preparing to deal effectively with the hugely complex threats that are associated with potential regime shifts in the agricultural system is a major challenge for decision makers in government and the private sector alike, and one that needs to be addressed as a matter of urgency. This talk will be on the management of emerging risks stemming from climate change aiming to identify the kind of policy actions that will need to be taken depending on the nature of climate change which is necessarily and inherently uncertain.

Climate change ranks highly among threats to the ability of food supply systems to meet growing demand through 2050 and could have major effects on food prices. Yield responses will precipitate significant adjustments throughout the global food supply chain. Starting at field level with alternative crop management practices and adjustments to the location and specialization of agricultural activities, climate change adaptations will affect international trade flows and consumption levels and spur targeted research and development efforts. The entire global food system will be challenged.

Changing climate necessitates in-depth, or transformational, changes in agricultural production systems that pose specific challenges to decision-making. As opposed to more incremental forms of adaptations, they imply large changes to either the location or the structure of regional food production capacity. Such adaptation options can be long-lived, and imply investment-intensive or of limited reversibility and need to be anticipated and planned. These investments will need to be committed *ex ante* to be ready to contribute to resilience at the times needed. However, such deliberateness is limited by large uncertainties on the aptness of specific transformations, which compound along a chain of assumptions regarding future emissions, climate response, crop response, and economic response. Due to their limited reversibility, transformations subsequently revealed to be inadequate or wrongheaded could lock agricultural systems into a maladaptive pathway, increasing vulnerability to changes in climate and turning investments into sunk costs. In addition, the potential future value of better information provides an incentive to postpone transformations.

In the talk insights into the transformations required of agricultural systems to face climate change will be presented. Specifically the following questions will be addressed:

What transformations are required from agricultural systems to buffer climate change impacts?

How robust are these transformations across scenarios?

The talk will conclude with a quantification of the value of information of improved foresight for the planning of transformative and adaptive climate adaptation measures. The value of learning and flexibility will be discussed taking cropping systems under uncertain climate change signals as the example.

The talk will conclude with a number of succinct policy conclusions addressing the need for transformative changes in the governance of the global agricultural system with the aim of increasing resilience to levels of acceptable risk.

09:00 Designing and assessing climate-smart cropping systems in temperate and tropical agriculture

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Climate change, particularly increasing temperatures and altered precipitation patterns, will affect dramatically food production systems in the next decades with regional and local differences. In Europe, grain yield stagnation and increased yield variability have been related in cereals to the recent climatic changes. In semi-arid West Africa, the onset and length of growing seasons should be modified by 2050 with yield reductions of 20–50%. Being partly responsible of the emissions of greenhouse gases (GHG) which contribute to global warming, agriculture has to reduce its carbon footprint while increasing biomass production to match the needs of a growing population. In a perspective of climate-smart agriculture (CSA), innovative cropping systems should be designed and combined in space with three objectives: reducing GHG emissions, coping with changing and fluctuating environments, and securing food production both in quantity, quality and diversity. Numerous studies reported positive or negative impacts of agriculture on GHG emissions. Until recently, studies addressing the vulnerability of crops to climate change were focusing on potential impacts without considering adaptation, but papers on that topic are now growing exponentially.

Breeding for new varieties better adapted to thermal shocks (heat, cold) and drought was suggested as long-term adaptation. Short-term strategies have been identified from current practices to take advantage of more favorable growing conditions or to offset negative impacts: shifting sowing dates, changing species, cultivars and crop rotations (*e.g.* double cropping, diversification), revising soil management, fertilization and plant protection practices, introducing or expanding irrigation. Some crops and cropping systems could move to more suitable locations. Crop diversification (at field, farm or territory level) could be recommended as a self-insurance measure to cope with more uncertain and fluctuant conditions and bring resilience to the system. The use efficiency of newly scarce resources should be increased: *e.g.* mulching in no-till systems for reducing soil runoff and evaporation especially under tropical conditions. Model-based tools and site-specific technology should be developed to optimize, support and secure farmer's decisions. Adaptation could range from tactical fine-tuning to deep changes in the nature of cropping systems with impacts downstream on land use and agricultural sector activity (machinery, inputs, market).

Agriculture can help improve the net GHG emissions balance via three levers: a reduction in N_2O and CH_4 emissions (and also CO_2 emissions), carbon storage in soil and biomass, and energy production (agrifuels, biogas), reducing emissions by replacing fossil energies (Pellerin Whitbread, 2013). Reducing the application of mineral N fertilizer is the main option for reducing N_2O emissions: a) directly by better adjusting N applications to crop requirements, making better use of organic fertilizers, or improving the efficiency of N supply; b) indirectly by increasing the proportion of N legumes in the rotation (as main crops or temporary grasslands). The second option is storing more carbon in soil and biomass by promoting no-till cropping practices (less fuel, crop residues), expanding the use of cover crops, and developing agroforestry. There is considerable scope for progress but, given the predominantly diffuse nature of the emissions and the complexity of the underlying processes, estimating emissions is riddled with uncertainty and the abatement potentials are currently less accurately quantified than in other sectors. Most of these solutions would not be affected by climate change. The introduction of legumes, which are relatively sensitive to water shortages and heat stress, could nevertheless be limited. A reduction in rainfall could also hinder the adoption of cover crops or agroforestry. Being relatively conservative, these options should have other positive impacts on the environment: less risk of pollution with reduced N fertilizer, soil and biodiversity conservation by planting trees or green covers. Using occasional tillage to solve severe weed problems should minimize the negative aspect of continuous no tillage on herbicide use. In addition, most of the adaptation options should have positive impacts on mitigation as well (*e.g.* measures for reducing soil erosion, conserving soil moisture and preventing nutrient losses, adjusting N and water rates to actualized yield goals, diversification of crop rotations…).

Designing cropping systems means proposing relevant combinations of crop species, varieties, practices and their spatial and time arrangement using experimentation, simulation, optimization or prototyping approaches. Assessment is generally supported by indicators or models to deal with multi-criteria issues according to the principles of CSA. That means to take into account a wide range of performances and impacts at field, farm or landscape levels. In this area, most of the studies are 'top-down' based on the exploration by model of a range of cropping systems in future climates. Multi-criteria and multi-attribute methods have been developed to assess *ex ante* the sustainability of innovative cropping systems (Bockstaller *et al.*, 2009). Crop simulation models offer research tools for evaluating trade-offs of potential innovations (robustness, resilience) and form the basis of decision-support systems for farmers, and tools for education and training. Matthews *et al.* (2013) identified 4 contribution areas for models: a) determine where and how well crops of the future will grow, b) contribute to crop improvement (ideotypes), c) identify what future crop practices will be appropriate for adaptation and/or mitigation purposes, d) assess risk to crop production in the face of greater climate variability. Biophysical models may be linked to economic, farm systems or livestock models to widen the scope of potential impacts, innovations and farm constraints (Webber *et al.*, 2014). Only a small subset of feasible changes has been simulated, some marginal (*e.g.* changing varieties, sowing times, irrigation amount) and other more systemic (*e.g.* conservation agriculture), in relation with model capacities. However cropping system models have major drawbacks related to the difficulty to consider multiple biotic and abiotic stresses and correctly represent the efficacy of crop practices and the farmer's decision plans. A broader range of innovations including resource allocations would necessitate models of the socio-ecological system.

Farmers have developed a wide range of anticipatory and reactive management strategies to cope with climate risks, but more frequent extreme events may exceed their adaptive capacities (Reid *et al.*, 2007). They are also generally unaware and/or unconcerned about future climate change and GHG emissions from agriculture. Therefore 'bottom up' participatory approaches have been developed to involve the stakeholders through interviews and focus groups in order to fully use their practical knowledge and their perception of climate change when tailoring local adaptation options (Willaume *et al.*, 2014). Hybrid methods have been developed combining both participation and research based-models (via serious games) in order to develop the adaptive capacity of farmers on real-world problems (Martin, 2015).

Socio-economic conditions, farm management and future resource availability (*e.g.* water for irrigation) are often ignored in adaptation and mitigation studies, although they influence feasible innovations (Reidsma *et al.*, 2010). Another challenge will be to model at different scales the direct impacts of cropping system changes and/or landscape composition and arrangement.

To illustrate the combination of methods when designing and assessing cropping systems for CSA, several case studies will be discussed from temperate and tropical conditions. How do they contribute to reduce the GHG emissions? What is their potential of adaptation to climate change? How do they contribute to food security?

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CONTRIBUTED ORAL PRESENTATIONS

11:00 Phosphorus use efficiency in symbiotic N_2 fixation for coupling bio-geochemical cycles in agrosystems with legumes

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Fewer chemical inputs, used as fertilizer or disease control, becomes of paramount importance for the safety and impact on the environment of agricultural production of food. This implies new requirements with regards to the selection of legume-crop varieties for grain cropping systems. Low phosphorus availability in about 40% of the world's arable land limits crop yield, most particularly for leguminous crops when their growth depends upon symbiotic N_2 fixation (SNF). Therefore, our work aims to increase the phosphorus use efficiency (PUE) for SNF, and its contribution to a more effective coupling between the P and N bio-geochemical cycles in agriculture and forestry. Myo-inositol hexakisphosphate (phytate) constitutes the main source of organic P in soils, but is unavailable to plants. Phytases are the only phosphatases able to hydrolyse phytate efficiently into inorganic Pi, thus increasing soil-P bio-availability for plants. In this work we demonstrate the existence of phytases, both histidine acid and beta-propeller, among rhizobia nodulating legume spp, and show their expression within nodule infected-cells. Plant phytase-gene expression was also found in nodules, and shown by in situ RT-PCR, to increase significantly under P-deficiency, and to vary among recombinant inbred lines of Phaseolus vulgaris that are contrasting in their PUE for SNF. A subsequent virtuous cycle of P and N fertility will be addressed in relation with the objective of the interdisciplinary research strategy of FABATROPIMED. The overall objective is to increase the benefit of grain-legumes for cereal systems and the environment by promoting the interaction between soil micro-organisms for plants to acquire and use N and P most efficiently. The field activities include a participatory approach with farmers in reference agroecosystems offering a wide range of agroclimatical and socioecological situations.

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11:15 Conservation agriculture and agroecology practices to mitigate climatic variations in medium altitude in Madagascar

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Conservation Agriculture (CA) has been promoted in the last 15 years in Madagascar to develop a sustainable rainfed agriculture in order to cope with low fertility upland soils, erosion, low local cropping system productivity and impact of climatic variations. We took the example of medium altitude areas (Lake Alaotra and Middle West of Vakinankatra province). If climate change is not proven in these areas, climatic variations are very high (in lake Alaotra for instance, rainfall varies from 500 to 1600 mm/year and rainy season from 2 to 5 months) and erratic rainfall patterns at the beginning of the rainy season do induce serous risks of crop failure.
In CA systems, the mulch resulting from rice straw, other plant residue and associated dedicated plant residues contributes to better cropping systems resilience and helps to mitigate climatic variations. If a limited number of farmers have effectively adopted in the long run CA, most farmers have developed intermediate cropping systems between conventional and CA that fit their own constraints and strategies, leading to a wide spread of some agroecological practices. But are such practices sufficient to cope with climate variations? Most farmers have to deal with the following trade-off: better resilience of upland cropping systems through CA practices (including Mulching) vs better immediate economic output. Changing the paradigm from conventional to conservation agriculture implies some risks and not only technical risks of crop failure. A typology of behavior is presented to identify farmers' strategies on risks in a world of multiple uncertainties (climatic, economic, and socio-political).

11:30 Agronomic and environmental benefits of climate-smart farming practices modeled for rice-based system in India

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To confront future challenges to food security exacerbated by climate change, there is an urgent need for the scientific community to operationalize the definition of climate-smart agriculture (CSA). However, one of the greatest challenges facing international donors and policymakers is the design of solutions with a multidimensional reach, from food production and food security, to water and energy usage. In this article, standard economic analysis in combination with a crop modeling software is used to investigate the effects of a set of alternative agronomic practices available to smallholders in India. Several alternative agricultural management practices are evaluated against the three pillars of CSA with a special emphasis on increasing sustainable production and resilience. We employed a modeling framework where a process-based model for agro-ecosystems driven by remote sensing data, national statistics database, and climatic scenarios is utilized to simulate a stress test for the relevant productive systems and identify best responses based on the assessment of current agricultural systems and practices and their sensitivity to climate and market risk. The portfolio of options that can increase productivity but are also resilient to the risks that arise from the changing climate is identified and a full characterization of the greenhouse gas emissions of the considered production systems is created so that the best options for CSA can be considered. We find that, given the local geophysical and economic conditions, it is difficult to identify a set of practices that is superior to all others and that the existence of triple win solution depends very much on how stakeholders value the several dimensions in which every production system delivers.

11:45 Smallholders' coffee and cocoa agroforestry systems; examples of climate-smart agriculture

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Agroforestry is an agricultural practice that integrates trees on cropping systems, farms and landscapes to diversify and sustain production. Agroforestry is one key management option for climate-smart agriculture as it combines sustainable production, adaptation and mitigation of climate change, as well as food and income security through tree-crop diversification. Trees in cocoa and coffee systems have been documented to improve crop production, provide timber, fruits and other products and ecosystem services, thereby enhancing food, nutrition and income security of smallholders that produce over 80% of world cocoa and coffee. There is increasing evidence that trees, through microclimatic amelioration, enhance the resilience of cocoa and coffee systems to climate change which is threatening the livelihood of rural communities globally. Nevertheless, intensification of the production of both coffee and cacao is currently promoted mainly via improved germplasm and use of agrochemicals in monoculture, and hence removal of shade trees which decreases smallholders' ability to cope with price volatility of coffee and cacao, pests and diseases outbreaks and climate change. Agroforestry systems are well suited for risk-averse smallholders.

To promote successfully an intensification of cocoa and coffee systems including agroforestry practices, two scientific approaches are currently combined: 1) participatory research taking into account local knowledge of rural communities on tree species compatibility with the main crop and suitability to match ecological niches, livelihood requirements of farmers while providing a range of ecosystem services; and 2) development of tools and models that evaluate the trade-offs or synergies in terms of resource capture and competition / facilitation between trees and the main crop in order to optimize tree species arrangement and shade management according to local conditions *e.g.* soil fertility, microclimate, elevation or solar radiation.

Parallel session L3.3
Climate-smart livestock

Wednesday, 18 March 2015

8:30 – 12:30

ROOM SULLY 3

KEYNOTE PRESENTATIONS

08:30 Climate-smart livestock systems: lessons and future research

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Livestock are an important global sector contributing significantly to the economies of countries and the food security and livelihoods of millions of people around the world. Livestock systems also have a large environmental footprint. They use 30% of the global land, 32% of water and emit around 18% of greenhouse gas emissions. The last two decades have seen a proliferation of work on livestock and climate change. The two main threads have been on mitigation of greenhouse gases and on adaptation to climate change. Initially these research agendas were studied independently. Recently, there is growing demand from decision-makers and policy to address them in a more integrated manner as their agenda has moved towards the development of solutions. Integration of these two aspects can exploit synergies and minimize trade-offs between mitigation and adaptation or avoid maladaptation that could potentially increase GHG footprint. This paper gives a brief account of the lessons learnt from this body of research.

Heterogeneous solutions for heterogeneous systems: Livestock systems are diverse for a variety of reasons including agroecology, physical location, production objectives, market orientation, and socio-economic context. 'Silver bullets' for climate challenges, like for many other aspects of agriculture, are elusive and are often not well suited to heterogeneous systems where impacts in one component of the system can lead to unintended consequences elsewhere. Maladaptation can be costly. We have also learnt that systems are constantly in transition due to a variety of drivers: population density, incomes, diet shifts, public perception, resource constraints and others. The study of climate-smart livestock systems needs to incorporate these aspects explicitly. This is about the futures of today and the evolution of the linked systems. Climate needs to be recognized as just one of many risk faced by livestock systems.

Most efforts still concentrated on technological fixes (incremental adaptation): What have we tried? Many practices associated with sustainable intensification: better feeds, genetics, health, improved pastures and others. These often show great technical potential, with increases in productivity, incomes and a reduction in emissions per unit of product, but not necessarily to reductions in gross emissions per household, hectare or enterprise. The reality is that many of these practices still exhibit low adoption rates due to lack of investment and research in incentives and policy instruments, promotion of market orientation, development of value chains and institutions, risk perceptions and others. These are crucial barriers that merit more attention. More effort is needed in incorporating the impacts of a variable climate on adaptation and mitigation strategies. This will likely lead to increased understanding of their constraints to adoption. We also recognize that incremental adaptation will only provide resilience to modest climate change and so some larger scale adaptation options will be required in order to ensure long-term viability.

Transformational adaptation needs to be considered in livestock systems. Some observations:

1. Structural change in livestock systems could lead to significant adaptation and mitigation. Systems shifts towards diversified mixed systems seem beneficial as yield gaps of crops and livestock are often large and can be exploited at low cost and risk. This strategy leads to net reductions in carbon dioxide equivalent emissions mostly through the indirect effects of reducing LUC and promoting land sparing, when demand targets are held constant.
2. The structure of some livestock systems (i.e. high population densities, too small farm sizes) might prevent further actionable agriculture and livestock adaptation and mitigation strategies. Identifying these areas is crucial.
3. Systems diversity is essential to prevent risks for the global food system: for example, over-reliance on monogastric systems at the expense of ruminant systems, for the sake of increased efficiencies would pose significant zoonotic and infectious disease risks for the provision of animal products.
4. Relocation of livestock production could be essential for food security and reducing environmental loads under climate change impacts.
5. Transformations need new modes of interaction between actors and new information. This understudied area merits further research.
6. Transformations are not cost-free, and this applies to many dimensions. There are many social impacts associated with transforming systems and these need to be properly studied. Additionally, transformations are not emissions nor resources-free, and new areas of production and new systems could be subject to significant perturbations in the process.

Policies are essential to achieve adaptation, mitigation and the sector's growth and to reduce leakage effects. Adapting livestock systems and intensifying them can be profitable, but profit can lead to expansion of operations and increased supply of animal products. Under these conditions mitigation is not achieved. Additionally, practices targeting reductions in emissions through land sparing can lead to substantial leakage and reallocation of emissions and growth in other sectors. Taxes and subsidies of different kinds can help regulate these processes. However, there are few tangible examples of how these can operate, especially in the developing world.

Livelihoods indicators and farmers objectives need to be better understood and at the centre of the agenda. The study of climate-smart livestock systems is still too biophysically centered. This is ironic as farmers are the smart ones, they have a wealth of knowledge that they use together with new information to make decisions about their systems and livelihoods. Unfortunately, we do not understand well how farmers and other actors make decisions, their political economy and their incentives, and this is crucial for developing solutions that will really be applicable in a variety of systems.

Towards climate and nutrition-smart livestock systems: The food security agenda is transforming into a nutritional security agenda due to the acknowledgement that human diets link nutrition, health and the environment. It is also recognized that managing the demand for livestock production could play a significant part in both reducing the adverse health impacts of overconsumption and improving malnutrition, while reducing the environmental footprints of livestock systems. Targeting climate and nutrition-smart research simultaneously could yield multidimensional benefits for society, our food systems and the planet.

09:00 Livestock and climate change: combining mitigation and adaptation options and projecting sustainable futures

Soussana Jean-François[1] and the EC FP7 'AnimalChange' consortium (see www.animalchange.eu)

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The demand for livestock products is growing and is expected to increase by 70% by 2050. Much of this is predicted to be in the form of pig and poultry meat and most growth will be in developing countries where livestock production is a key contributor to rural livelihoods. Climate change will threaten both food security and rural livelihoods through heat waves, changing patterns of rainfall, increasing incidence of extreme weather and changing distribution of diseases and their vectors. But it will also present opportunities. The global animal food chain and associated land use change is estimated to generate 14% of global greenhouse gas (GHG) emissions. However, there are large uncertainties and we cannot adequately characterize trade-offs in terms of emission reduction, food production and economic development under climate change. Thus policies that are currently in place to curb GHG emissions and adapt livestock systems to climate change may prove insufficient.

It is within this context that the AnimalChange project has provided a vision of the future of the global livestock sector under climate change by developing a consistent suite of scenarios, models, assessments and policy support tools to: reduce uncertainties concerning GHG emissions from livestock systems; include climate variability as part of climate impact assessment; provide technologies for mitigation and adaptation to climate change; assess economic and societal costs and opportunities of business as usual and of adaptation and mitigation scenarios; assess the vulnerability of livestock to climate change and feedbacks on GHG emissions; provide direct support to establish policies for mitigation and adaptation to climate change for the livestock sector; reach out to stakeholders by organizing symposia, training of scientists, technicians and policy makers. The project has four scientific components: livestock systems under business as usual scenarios, assessment of mitigation and adaptation (M&A) options, combining M&A options at the farm scale and assessing regional changes in livestock systems.

Global and regional livestock sector scenarios: Shared Socio-economic Pathways (SSPs) were developed for key drivers of the livestock sector. New datasets for climate scenarios were made available. Representative Carbon Pathways (RCPs) were used to project climate change impacts on grasslands and livestock systems in combination with SSPs based on a cluster of models (Globiom, Capri and Aropaj). Results show possible sustainable futures for livestock systems.

Reducing uncertainties for current livestock GHG emissions: Further development of the MITERRA-Global model has shown the spatial distribution, together with an uncertainty analysis, of GHG fluxes in Europe, Africa and Latin America. An ensemble of grassland and cropland models were applied to project changes in production and GHG emissions in Europe – and on a global scale with grasslands – for contrasted RCP scenarios. Moreover, the potential enteric methane (CH_4) production from forages from Africa and Latin America was studied, together with CH_4 emissions measurements from grazing ruminants and slurries in Africa. Soil carbon stocks and eddy covariance measurements of CO_2 fluxes point to the role of grazing management and nutrients balance as major drivers of carbon sequestration in both temperate and tropical grasslands.

Climate change impacts, vulnerability and feed-backs: A statistical modelling framework for vector-borne diseases has been developed indicating increased risks from climate change for the spread of some of these vectors. Novel methods to reduce risks from an increased pressure of enteric parasites at grazing have been developed for tropical grazing systems. The vulnerability of crops and pastures production has been compared for a range of RCP scenarios and assessed using a probabilistic framework for vulnerability analysis. On average, results show that arable crop yields are more at risk under climate change than the annual production of grasslands. Nevertheless, increased risks of seasonal herbage production failures from droughts raise adaptation challenges for grazing systems.

Mitigation options: Significant benefits of increased legume usage in pastures and variable benefits of high sugar grasses have been shown. A range of mitigation options has been compared based on experimental work in sheep, cattle and pigs in intensive systems, large scale analysis on the use of additives to decrease methane emissions from ruminants and horizon scanning actions for rumen function, animal genetics and manure management.

Adaptation options: Excess heat impacts on pig and sow production have been assessed showing the role of body size, diets and building environment. With small ruminants in the wet tropics, adaptation options reduced gastro-intestinal parasites effects based on mixed grazing, diet supplementation and vermicomposting. Grassland adaptation was assessed showing increased resilience to heat and drought of forage grass populations from Mediterranean compared to temperate origins and of mixed swards compared to monocultures.

Integrating adaptation and mitigation (A&M) options: A qualitative overview of A&M options and their possible synergies and trade-offs has been delivered, as well as process based estimates of A&M options. Data have been assembled for model farms in Europe, Africa and Brazil. These virtual farms represent a livestock system in a region, based on a combination of estimated regional production systems data and national statistics. Data from showcase farms, which are real farms, were also assembled and used in calculations of model farms. The FarmAC model has been developed, together with an Internet-based user interface and an interface to allow modification of model parameters, which will contribute to sustainability assessment of livestock farming systems by providing a Tier 3 methodology for assessing flows and losses of C and N. 24 model farms and experts were identified which represent current and future farming livestock systems. For each a list of preferred A&M options has been built and assessed with the FarmAC model. Data required for the economic analysis of A&M options were collected to outline the economic assessment of A&M options, and the policy environment for climate change in which livestock must be located.

Regional scale A&M: To determine barriers to realizing the full technical potential of A/M measures, data was collected and analyzed on the case study regions of Western Scotland, Southern Spain and Kenya to provide the basis for regionalizing the constraints to meeting technical potential of measures. A modelling framework has been developed and applied in full to Scotland. A report was issued presenting three main policy scenarios: i) implementing win-win mitigation measures, ii) implementing all technically feasible mitigation actions identified, iii) implementing all measures with a cost below a carbon price threshold. A white paper on key policy issues for the European livestock sector with regard to climate change is being developed.

CONTRIBUTED ORAL PRESENTATIONS

11:00 Differential climate change impacts on crop and grasslands and the relative livestock production systems competitiveness

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The climate change will impact livestock in many ways going from heat stress through livestock diseases to feed quality and availability. Recently, projected climate change impacts on crop and grassland productivity became available with high spatial resolution at global scale. The objective of this paper is to investigate how climate change impacts on crops and grassland will influence livestock production globally and its distribution across regions.

This analysis is carried out using the global partial equilibrium agricultural and forestry sector model GLOBIOM. The model represents agricultural production at a spatial resolution going down to 5 x 5 minutes of arc. Crop and grassland productivities are estimated by means of biophysical process based models (EPIC and CENTURY) at this resolution for current and future climate. Livestock representation follows a simplified version of the Seré and Steinfeld (1996) production system classification. This approach recognizes differences in feed base and productivities between grazing and mixed crop-livestock production systems across different agroecological zones (arid, humid, temperate/highlands).

Our study highlights that the differential impacts of climate change on crop and grassland productivity will influence the relative competitiveness of different livestock production systems. Most interestingly, under some climate change scenarios, grass productivity is favored compared to crops, and this phenomenon could lead to a slowdown, or even reversal, in the trend of declining share of livestock production in grazing systems. Maintaining livestock production in some regions will depend on their capacity to adapt. Institutional and physical infrastructure will be needed to facilitate these transformations.

11:15 Efficiency gains for enteric methane mitigation and productivity: contribution to CSA and investment opportunities

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Methane emissions from enteric fermentation account for about 35% of global methane emissions and 70% of methane emissions from agriculture. They represent a loss of energy for livestock production of about 153 million tonnes oil-eq. per year.
Enteric methane emissions are a natural process related to the digestion of ruminants. Rumination however also allows cattle, sheep and goats to digest fibrous feeds that cannot be directly consumed by humans and thus to make a net positive contribution to food balances. Today, ruminants are estimated to account for 51% of all protein supplied by livestock.
While fully avoiding enteric methane emissions is not achievable in the short term, opportunities exist to substantially reduce emissions per unit of product, *i.e.* emission intensity, especially in systems operating at low levels of productivity. These options generally consist in improving the efficiency of production via the implementation of known practices that result in greater output per animal and per unit of feed. Opportunities exist at all levels of production and include a variety of interventions, from feeding, to animal health, breeding, reproduction and off-take management. For example, estimates show that moderate improvements in feeding, animal health and breeding management could reduce emission intensities by ca. a quarter in South Asia.
Mitigation options focussing on improved efficiency in developing regions have the particular advantage of offering synergies between emission reduction, increased productivity, and other environmental objectives such as reduced land degradation. A number of initiatives gather global and regional players towards the development of technical packages, policy frameworks and monitoring, reporting and verification methodologies that can result in practice change on the ground.

The paper will take stock of current initiatives, discuss the potential of the approach within the context of CSA and highlight investment opportunities.

11:30 Variations in egg incubation temperature enable chicken acclimation through long-lasting changes in energy metabolism

Loyau Thomas[1], Métayer-Coustard Sonia[1], Berri Cécile[1], Mignon-Grasteau Sandrine[1], Hennequet-Antier Christelle[1], Praud Christophe[1], Duclos Michel J.[1], Tesseraud Sophie[1], Coustham Vincent[1], Nyuiadzi Dzidzo[1,2], David Sarah-Anne[1], Everaert Nadia[3,4], Siegel Paul B.[5], Yalçin Servet[6], Yahav Shlomo[7], Collin Anne[1]

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Poultry production has increased during recent decades in hot climates where extreme temperatures are predicted to occur more frequently than in Europe. To limit the negative effects of temperature fluctuations on performance and welfare of chickens, an innovative strategy inducing hot or cold acclimation of embryos was established. The long-term effects of changes in chicken egg incubation temperature were studied to understand the physiological and metabolic mechanisms involved in early acclimation, according to the objectives of INRA Metaprogramme ACCAF. Cyclic increases in egg incubation temperature had little effect on hatchability and performance but caused a decline in body temperature of males from hatching to 28 days. They affected plasma thyroid hormones concentrations that regulate heat production, and changed respiratory physiology and stress markers in the long term. Heritabilities were moderate for comb temperature during a heat challenge and the ratio of thyroid hormone concentrations T_3/T_4, suggesting traits relevant to consider in selecting for heat-tolerance in chickens. Chickens having experienced heat during incubation exhibited a lower stimulation of energy metabolism in the liver and breast muscle. Conversely, the use of cyclically cooler incubation temperatures triggered mechanisms limiting oxidative stress at hatching and had long-term effects on mechanisms promoting heat production. These regulations could involve epigenetic mechanisms, such as changes in the methylation status of DNA or histones modifications. Innovative strategies of egg incubation should now be evaluated according to criteria defining sustainability, including not only the effects of these practices on performances of poultry production systems, but also their environmental and social impacts in temperate and hot countries.

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11:45 Impact of feeding strategies on GHG emissions, income over feed cost and economic efficiency on milk production

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Costa Rica's commitment to carbon neutrality has prompted the development of a policy initiative that prioritizes climate smart actions including mitigation of greenhouse gases (GHG) emission. This research characterized management strategies in 104 farms, their partial emission (enteric methane and nitrous oxide from synthetic fertilizers and cows' effluent deposited in pasture), and estimated their economic efficiency. Diet ingredient composition and cow performance data were collected with a survey, energy expenditure and dry matter intake were determined with NRC equations, and emissions were estimated with IPCC equations. A cluster analysis resulted in the identification of 4 distinct feeding strategies based on relative reliance of pasture, concentrate, by-products or cut-and-carry grasses. Compared with a pasture-based feeding strategies, using a higher proportion of concentrates in the diet resulted in higher feed costs but also higher income over feed cost (IOFC = milk sale minus diet cost). Greater reliance on pasture resulted in lower milk production and higher emissions per unit of milk. Classifying farms according to partial GHG emissions resulted in three distinct clusters. Partial emission was 85% greater for the highest compared with the lowest emitting farms. Discriminant analysis identified 11 variables responsible for the variation in partial emission. In spite of higher IOFC, farms that were characterized by increased use of concentrates resulted in significantly lower economic efficiency compared to farms using predominantly grassland-based strategies. Intensification, which in this study was related to external inputs, was associated with higher management costs and emission tradeoffs within the farm (concentrate feeds reduced enteric methane, but N fertilizer increased nitrous oxide emission). On-farm climate smart solutions are needed to improve economic and environmental efficiency. Findings of this study have important implications on mitigation actions of the livestock sector.

Parallel session L3.4
Climate-smart landscapes, watersheds and territories

Wednesday, 18 March 2015

8:30 – 12:30

ROOM RONDELET

KEYNOTE PRESENTATIONS

08:30 Climate Smart Territories; what are they and how do we evaluate progress towards this goal?

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This congress demonstrates the high level of attention that is being given to Climate Smart Agriculture (CSA); *i.e.*, CSA is recognized as an excellent framework which addresses issues of food security, mitigation of climate change and adaptation (resilience) to a multitude of factors, with particular relevance for small tropical farms which are most at risk from the consequences of climate variability and change. The logical next step has already been taken with many organizations developing climate smart concepts and initiatives that take the broader viewpoint of the landscape (*e.g.*, EcoAgriculture Partners; ICRAF), Territory (*e.g.*, CATIE) or region (*e.g.*, Bioversity). Logical because: 1) agriculture (or any other land use) should not be developed in isolation of surrounding land use; 2) environmental (or ecosystem) services, which are key for adaptation, mostly are provided by a territory rather than a farm or plot; 3) conflict resolution over access to resources and services requires the participation of a range of actors with different interests; 4) mitigation options can´t be addressed only at the plot level (*e.g.*, issues of ¨leakage¨).

System approaches used in research and development interventions in many tropical countries (*e.g.*, value chains; agroecology and agroforestry; livelihoods and community capitals; and territorial) are well developed though the potential gains from integrating them have not been fully realized. Territorial/landscape approaches (watershed management; biological corridors; buffer zones and national parks; model forests, integrated rural development projects; etc) are not new though the integration and use of information over different scales is still a challenge. The importance of understanding the political, regulatory, economic and social framework within which development initiatives will either thrive or fail is clear. Contributing inputs for science-based decision-making (*e.g.*, reformulation of policies and rules) has become a new challenge for researchers who are charged to develop impact pathways and theories of change (*cf*. CGIAR). All of these existing areas of work are key for the development of Climate Smart Territories (CST).

The interventions involved when seeking to create a CST are not new. What is new is the way we integrate information and make key land use decisions in a transdisciplinary manner; *i.e.*, using a wide range of disciplinary expertise and traditional knowledge, integrating a range of interest groups, building from the farmers' context all the way up to national policy. The backbone of CST initiatives is a co-learning process whereby a diverse group of stakeholders assess, analyze and discuss, seeking agreement on the key decisions about the use of the resources in their territory (*e.g.*, CATIE´s Focuencas and Ecoadapt projects). A robust practical monitoring and evaluation (M&E) system is needed to follow up on key activities so that diverse actors (private sector including both companies and farmer cooperatives; local government; NGO´s; etc.) can judge to what degree their decisions and actions are contributing to a CST. It should provide easy access to information in order to make science based decisions in a participatory way.

Long-term financing to create and maintain CST initiatives will depend on the availability of local resources; thus investments in CST have to result in benefits for the stakeholders. Once again conflict resolution comes to the forefront because one or more persons´ profit could be reduced by a CST approach that benefits the rest of society; *e.g.*, when there is better control of tree felling. Mechanisms and institutions are needed to coordinate and aggregate financing, both enabling and asset investments, for CST at scale within territories and across sectors.

The search for a succinct set of key variables (criteria/ indicators) to judge the level of climate smartness of a territory, and hence the effectiveness of our interventions, leads us to consider proxy variables which reflect a large number of underlying variables related to good (and hence Climate Smart) land use. One of these is tree cover, which is known to be related to a wide range of ecosystem services that contribute to our climate smart goals and indeed to the very survival of societies (*cf*., see examples in Jared Diamond´s book ¨Collapse: How Societies Choose to Fail or Succeed¨). Four key results that can be used to show that a territory is climate smart are: adaptation measures are successful; emissions are lower than for business as usual practices; income, education and health have improved (HDI for example); greater equity has been reached in terms of decision-making and access to community capitals.

Decades ago the forester sector developed principles, criteria and indicators for sustainable forest management; however early attempts often resulted in long lists and complex procedures. Another useful source of experience and reference for CST are the certification and payment of environmental service schemes that have been developed and adapted in many tropical countries to evaluate whether certain good practices are being implemented and whether they meet their goals and commitments. These schemes face the same challenge of developing low cost but reliable monitoring mechanisms, applicable to large numbers of small farmers, which guarantee that the buyer of the service (could be a government or international agency in the case of CST) gets what he or she is paying for.

In CATIE´s Mesoamerican Agroenvironmental Programme (MAP), key variables are food security and nutrition, agriculture diversification and intensification, the use of agricultural innovations producing co-benefits (adaptation and mitigation), sustainable production of ecosystem services (using tree cover as a proxy), increased participation of women and youth in decision-making, producer organizations with greater access to competitive and equitable value chains, and the existence of enabling conditions such as policies and planning frameworks favorable to CST. Large-scale restoration of soils, grasslands, forests, designed for other benefits (increased agriculture production, biodiversity conservation, watershed function, disaster risk reduction), can contribute to climate change adaptation and mitigation

The Hojancha (Costa Rica) model forest, where major positive changes in land use have occurred over the past 30 years, is an example of what a CST could look like. Key factors that led to this success were the need to respond to an economic and environmental crisis (and outmigration); the existence of local leadership; a sense of identity and unity; good political connections at higher levels; national policies that promoted conservation; access to technical assistance.

Constructing a CST will always be a work in progress, constantly adapting to changing conditions. The principle requirements are a shared vision among stakeholders; institutional platforms for dialogue, negotiation and planning; promotion of land use practices that have multiple functions, as well as providing climate change mitigation and adaptation benefits; alignment of policies and markets; explicit management of synergies and trade-offs between different stakeholders.

09:00 Towards climate smart landscapes and watersheds

Oswald-Spring Úrsula

CRIM-UNAM, Mexico

Latin America accounts for 40% of the world's biodiversity, 25% of world's forests, and over 98% of which are natural forests and not plantations. Latin America has shown leadership in community forestry (Seymour 1994), due to the recognition of the rights of peasant and indigenous communities to establish their rules for the access and use of the forest. Nevertheless, population growth, urbanization and mining are altering the favourable natural and social conditions, creating often conflicts and migration, which are reinforced by conflicts and organized crime linked to logging. Deforestation, unsustainable basin management and invasion in the watersheds have also increased anthropogenic risks, which are triggered by extreme climate events. Thus, a stakeholder engagement and the reinforcement of traditional community institutions are crucial for a successful community forest management (CFM). REDD+, horizontal leadership, and the payment for environmental services (PES) with sustainable logging offer bases for a successful CFM. Capacity building is crucial and grants better outcomes when it is bottom-up built and the government is supporting the skills of the people by taking into account Ostrom's approach of the commons. From practice, through local governance, negotiation of conflicts, transparency in finances and up-scaling to neighbouring forests capacity building and management reduce leakage and enhance both ecosystem service payment and sustainability. Regional differences are crucial to take into account, especially in mountain areas: a low intensity forestry intervention (LIFI) in the top of the watershed increases the infiltration of precipitation, reduces risks of flash floods in the plain and recovers aquifers, water that can be used for human consumption, irrigation of crops, and industrial transformation. Therefore effective basin management with CFM means a sustainable recuperation of the whole watershed. Sustainable CFM upstream and efficient land use for agriculture and human settlements downstream are key elements for reducing also disaster risks (DRR), improving the diversification of jobs, thus wellbeing and livelihood for people, and a sustainable management of ecosystem services and landscape.

The paper presents first a general overview about Latin America's biodiversity. Then focuses on empowerment of communities in sustainable CFM, where national laws are adapted to customer local and regional laws together with stakeholder engagement. Capacity building from bottom-up and PES, REDD+ and low impact of forest logging are conserving ecosystem services, providing goods and therefore improving income and livelihood. The empowerment of community by promoting their traditional laws and customs has enhanced sustainable CFM and additional productive activities (handicrafts) have alleviated poverty. Strong community management, collective decision-making processes and negotiating conflicts has reinforced the system of rules and protected the community from external pressure, especially the organized crime. Sustainability is only achieved when the dual vulnerability, the social and the environmental, is overcome and the CFM is up-scaled within a scheme of integrated basin management with participative governance and strong stakeholder engagement, where the whole watershed gets benefits, livelihood and social integration.

CONTRIBUTED ORAL PRESENTATIONS

11:00 Prototyping climate-smart agricultural landscapes: a generic modelling framework and application in a tropical island

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In order to seek opportunities to mitigate emissions of greenhouse gases, increase carbon sequestration and build capacity of agricultural systems to adapt to climate change, innovative climate smart agricultural landscapes satisfying multiple sustainability goals have to be designed. Whereas several qualitative methods have been proposed to design new agricultural landscapes, we lack a holistic, quantitative, spatially explicit and integrated modelling framework to design new agricultural landscapes as a function of adaptation strategies. In this paper, we propose such a modeling framework, based on a scenario approach coupled to an optimization model which prototypes cropping system mosaics at the landscape scale. The finality of the modeling framework is to identify levers for building climate smart agricultural landscapes. To simulate the land use change, our modelling framework includes a bio-economic model that explicitly accounts for scenarios of 1) policies, markets and sustainability issues, 2) farmers' decision process and 3) cropping system performances at the field scale, under heterogeneous socio-economic and biophysical farming situations. The modelling framework also includes a set of indicators aimed at assessing quantitatively the ability of the designed landscapes to be climate-smart. The implementation of the framework in Guadeloupe, a 1800km^2 tropical island, proved to be relevant since we designed prototypes of climate-smart agricultural landscape satisfying the several sustainability goals targeted: climate change adaptation, sequestration of soil C, the increase in food and energy self-sufficiency and the decrease of the risk of pollution in water catchments. By providing quantitative information on the impacts of adaptation scenarios and on the trade-offs that have to be made, the framework can help policy makers to build a "triple win" climate-smart agriculture increasing food security, adaptation and mitigation.

11:15 Managing trade-offs in climate-smart landscapes: a global analysis at multiple levels

Locatelli Bruno[1], Pramova Emilia[2], Chazarin Florie[2], Fedele Giacomo[3]

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An adequate management of land uses and human activities in landscapes can contribute to climate change mitigation and the adaptation of societies to climate variations, while ensuring that the direct and indirect impacts of climate change on landscapes and their ecosystems are anticipated and minimized. The challenge is to implement an effective combination of approaches to understand, manage, avoid or accept the multiple possible trade-offs between the three objectives of climate-smart landscapes (societal adaptation, climate change mitigation, and ecological resilience). One of the barriers for broad implementation of climate-smart landscape strategies is the lack of information on the synergies and trade-offs between the three objectives, the added value of integrated strategies, and the context in which they should be pursued. We present an analysis of existing information on climate-smart landscapes at multiple levels. First, we review 100+ scientific papers on the interaction between the three climate objectives. Second, we report an assessment of how 200+ climate change projects worldwide in agriculture and forestry consider multiple climate objectives. Third, we present how this integration is considered in global climate funds based on the perceptions of fund managers. Several major narratives on climate-smart landscapes emerge from the cross-level analyses at the international, national and local levels about the integration of different climate objectives into landscape related activities. Finally, we discuss factors that can facilitate the development of climate-smart landscapes.

11:30 Climate-smart landscapes: multifunctionality in practice

Minang Peter A., Van Noordwijk Meine, Duguma Lalisa A.

ICRAF, UN Avenue, Gigiri, P O Box 30677-00100, Nairobi, Kenya

Landscape approaches present opportunities for sustainable development by enhancing opportunities for synergy between multiple objectives in landscapes (*i.e.* social, economic and environmental). This paper presents summary findings of a book from several years of work on climate-smart and multifunctional landscapes. It challenges the 'one-place-one-function' concept of specialization that sees agriculture, forest and urban spheres as separate silos. Drawing on a large range of case studies from predominantly the humid, sub-humid and dry tropics across the world, this book provides directly applicable knowledge, while also highlighting key issues requiring further work. The 27 chapters of the book are framed around 4 propositions relating to the sub-optimal nature of current landscapes, how interactions in landscapes can nudge change, climate as a boundary condition in landscapes and interactions between "theories of change" and "theories of place". It proposes landscape democracy and systems engineering as potential approaches to increasing effectiveness, efficiency and equity in multifunctional landscapes.

11:45 A platform for landscape ecoefficiency monitoring and jurisdictional certification in the Amazon region

Ferreira Joice[1], Poccard-Chapuis René[2], Laurent François[3], Plassin Sophie[2], Thalês Marcelo[4], Moura Fabricia[4], Pimentel Gustavo[5], Piketty Marie-Gabrielle[6]

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The process of deforestation in the Brazilian Amazon region during the six last decades has built disorganized landscapes, in terms of agronomic, ecological, economic and social aspects. Pastures were implanted after slash-and-burn, in a spatially systematic diffusion, buffering the road network with a land tenure objective, and with no consideration for topography or other natural resources, except hydrographic network for watering cattle. This spatial pattern of colonization has generated a large waste of space and natural resources. Since ten years, the zero deforestation policies are building a new legal context for land use and natural resources management, opening possibilities for landscape optimization for ecosystemic services and ecological intensification. To repair environmental liabilities, to connect remaining forest and preserve landscapes, to protect hydrolocical resources, to manage the land tenure and agricultural diversification, local actors need a tool to take into account the spatial distribution of the environmental, economic, agronomic and social organization in each jurisdiction.

The authors present in this communication a GIS tool at the municipality level, able to support the local actors' decisions and interrogations to build new ecoefficient landscapes, in order to mitigate emissions, optimize natural resources productivities, farm profitability and to plan local policies such as localizing logistics or agro-industrial plants. The main options about land-use changes, mitigation practices, pasture management practices, use of fire, are informed with a remote sensing set of indicators, crossing land tenure layers, and forest connection metrics.

The participative use of this tool should help local multistakeholders platform to monitor, evaluate and plan innovation, mitigation, diversification and synergies at the landscape scale, and improve the local governance's inclusion of smallholders. An external certification of this system at a jurisdictional level will be provided, demonstrating that local institutions can assume environmental responsibilities, and attracting new investors in a green economy perspective.

Parallel session L3.5
Investment opportunities and funding instruments

Wednesday, 18 March 2015

8:30 – 12:30

ROOM BARTHEZ

KEYNOTE PRESENTATIONS

08:30 Delivering Climate Smart Agriculture: prospects from climate finance

Hedger Merylyn, Nakhooda Smita, Norman Marigold

Overseas Development Institute, London, United Kingdom

The presentation will consist of three main parts:

1. A description of the background issues relating to climate change finance and agriculture
2. An overview of the current scene and its possibilities for change
3. An assessment of key next steps

1. Background

Agriculture is both victim and villain in respect of climate change. Victim because agriculture, and consequently food security and livelihoods, is already being affected by climate change, according to the latest science from the IPCC[1]. The IPCC has found that the world needs to produce at least 50% more food than we do today in order to meet the goal of feeding a projected 9 billion people by 2050. This must be achieved in the face of climatic volatility and change, growing constraints on water and land for crops and livestock, and declining wild capture fishery stocks.

Agriculture can also to be seen a "Villain" because it is a key source for greenhouse gas emissions. It is the largest source of global emissions for nitrous oxide- predominantly from chemical fertiliser; methane-predominantly from livestock reduction, and also a significant source of carbon emissions from land use change, mainly deforestation, excluding peat degradation, peat fires and food processing. Yet agriculture may also be part of the climate change solution: there is a considerable technical mitigation for carbon in soils[2] particularly in developing countries.

Although the protection of food security lies within the core objective of the UN Framework Convention on Climate Change (UNFCCC) (Article 2), no formal arrangements for addressing agriculture specifically within the negotiations have been agreed. Agriculture has been the engine of growth in the past for most of the world's economies, and many of the world's poorest are dependent on small-holder agriculture for their livelihoods. Consequently, agriculture is embedded within key areas of national economies and resistance has been shown, not only within the UNFCCC but also at the WTO, to policy interventions driven from international level. Yet, whilst not having a clear profile within the UNFCCC negotiations, agriculture is now embedded in key areas.

It is axiomatic that a post 2020 deal depends on developed countries delivering finance to help developing countries respond to climate change: the current goal is for $100 billion per year by 2020. The ideal balance of public to private sources is contested[3].

[1] IPCC 2014 Climate Change 2014 Synthesis Reported; Core Writing Team, R.K. Pachauri and L. Meyer

[2] IPCC 2007 assessed technical mitigation potential for carbon in soils of 6.000 Mt CO_2e/yr

[3] In 2012 there were more than 50 international public funds, 60 carbon markets, and 6,000 private equity funds already providing "green finance". Source: UNDP (2012) Readiness for Transformative Climate Finance: A framework for understanding what it means to use climate finance. UNDP New York.

2. Overview of current scene

The international community has more than a decade of experience helping developing countries address climate change through multilateral climate funds such as the Global Environment Facility, the first operating entity of the financial mechanism of the UNFCCC, the Adaptation Fund, and newer initiatives such as the Climate Investment Funds. More than $12 billion in finance has been committed to such funds over the past six years alone. In addition, a number of developing countries, including Brazil and Indonesia, have created national climate funds to raise finance from the international community for climate action.

Despite the significant potential of sustainable climate smart agriculture there has been relatively modest emphasis from existing climate funds. Between 2004 and 2014, 11 multilateral funds[4] programmed US$435 million across 90 projects supporting climate smart agriculture. This represents around 5% of tracked multilateral climate finance over the period. However agriculture and food security have been targets for financial support from the Least Developed Countries Fund and Pilot Programme for Climate Resilience, which align funding allocations with national priorities.

More than 93% of finance for agricultural projects has tended to flow towards adaptation activities. These investments cover altering crops and crop varieties, improving the effectiveness of crop and livestock management practices, altering the timing of cropping or Small Holder Adaptation Programme and seeks to incorporate climate change into its country programming. The Bio Carbon Fund Initiative for Sustainable Forest Landscapes targets agricultural drivers of deforestation. The new GEF 2020 strategy is now also seeking to target agriculture.

With the current operationalization of the Green Climate Fund (GCF), which is already the largest multilateral global climate fund with over US$10 billion mobilised in 2014 and more than US$100 billion expected to be mobilised annually by 2020, there are significant opportunities for multilateral climate funds to support sustainable climate smart agriculture through their investments.

This part of the presentation will look at current developments in this critical year 2015, where not only is a new climate agreement for the post 2020 period due at the COP in Paris, but also new SDGs are being developed and new developments are emerging around the Finance for Development agenda (FFD). The following areas will be explored.

The possible outcome on finance in a new UNFCCC agreement:

- Operationalisation of the Green Climate Fund and future of the international climate finance architecture;
- Greening global investment flows: making the links with efforts to mobilise finance for development;
- The changing policy environment at national level. (Once the focus moves from international negotiation to implementation, past experience with the preparation of NAPAs and NAMAs suggests that agriculture and food security issues are likely to assume major importance in national policy-making discussions, these may be reflected in the new INDCs).

[4] Including 9 international climate funds: The Adaptation Fund (AF); Clean Technology Fund (CTF); Forest Investment Programme (FIP); Forest Carbon Partnership Facility (FCPF); Global Environment Facility (GEF) (with a focus on activities under its fifth replenishment); Least Developed Countries Fund (LDCF); Pilot Programme on Climate Resilience (PPCR); Scaling Up Renewable Energy Programme (SREP); Special Climate Change Fund (SCCF) As well as two national funds: The Amazon Fund and The Indonesia Climate Change Trust Fund.

3. Next steps

Climate funds can more systematically support sustainable climate smart agriculture. The Green Climate Fund is already considering such an approach, having identified climate smart agriculture as a core priority area for investment. Understanding how to best programme finance to deliver the most impact will be critical. The following questions will need to be answered:

- Where and how should finance for climate smart agriculture be targeted?
- How will the national and international levels interact?
- How do you overcome uncertainties around accounting in order to ensure effectiveness of climate finance?
- How can integration of adaptation and mitigation interventions in land-use sectors be achieved to increase effectiveness of climate finance?
- Can funding for sustainable development (FFD) be a more effective route to deliver CSA?

09:00 "What Can Fund Climate Smart Agriculture?"

Searchinger Timothy D.

Princeton University, USA

How can the world fund Climate Smart Agriculture (CSA)? The answers depend first on what CSA is and will differ by its components.

The original focus on CSA was largely on replenishing soil carbon. The idea was that soil carbon could be a triple win: removing carbon from the air, improving productivity and improving crop resilience. Although increasing soil carbon is an important measure for boosting yields in many regions, including sub-Saharan Africa, recent papers have raised doubts about the practicalities of doing so in light of competing demands for residues as well as the likelihood that such efforts could be large enough to significantly mitigate greenhouse gas emissions.

A second major focus of CSA focuses on "sustainable intensification," which at root means increasing the efficiency with which agriculture uses resources, including fertilizer, energy, water, and animals.

A third focus is on the measures necessary to adapt to climate change, which will include adaptations to changed rainfall patterns, higher temperatures, and new disease and pest risks. In addition to physical measures, such as shifting crop mixes or breeding more drought-, flood-, disease- or saline-tolerant crops, these measures may include social interventions to allow farmers to withstand more variable weather cycles.

The fourth focus, although part of sustainable intensification, involves the particular need to produce more food on the existing agricultural lands and therefore avoid the clearing of forests, woody savannas and wetlands. As several papers have pointed out, one challenge is that the yield gains needed to limit land use change globally will often trigger additional land use change locally.

These elements highlight that CSA is only in part different from merely good agriculture. Even without any concerns for climate change, agriculture will need to boost yields, deal with diseases, care for soils, and make better use of natural resources. It is the sheer scope of future food needs that create the urgent need for more action. The needed funding for CSA is the funding needed to achieve this additional progress – the "delta" – and focusing resources on these additional efforts beyond those that would occur anyway represents part of the challenge.

The vast bulk of agricultural investments will have to come from the private sector. Inevitably, the private sector will respond to the factors it always responds to: prices, costs, risks, land use rules, and security of investment. The immediate question is how public policy can supplement and push these investments in the right direction. With these thoughts in mind, here is a discussion of some of the basic options for government funding.

Carbon credits: In original incarnations, hope for funding CSA rested heavily on carbon credits, with the expectation that power plants and others subject to greenhouse gas limitations in the developed world would pay farmers globally for carbon sequestration. One reason these credits have not fully materialized is the limited carbon regulations in developed countries. But there are also other large obstacles. They include the uncertainty and potential temporariness of carbon sequestration, large transaction costs, and the needs of farmers for upfront payments while purchasers wish to pay for credits already generated. Perhaps more fundamentally, the world needs both to reduce energy emissions and agricultural emissions to stabilize the climate. Using agriculture to replace energy mitigation means less total reduction. Finally, many of the opportunities for sustainable intensification will involve absolute increases in emissions but reductions in emission intensity, and it will be hard to use credits for such measures. With some exceptions, carbon credits are not a likely major source of funding for CSA.

Research: Governments globally spend only around $30 billion per year on agricultural research and investment, and spending is particularly low in many countries that are most food-insecure. Advances in molecular biology have increased the tools for meeting CSA challenges. There will be no substitute for further public investments, particularly in many of the poorest countries where national efforts must be supported by consistent streams of international funding.

REDD+, Foreign Aid & Infrastructure Spending: Although the world has a strong interest in preserving its forests and woody savannas, financial incentives from developed countries to tropical countries have a strong role to play. To avoid leakage of agriculture to other regions, this support should ideally encourage improved yields and adaptation of agriculture on its existing footprint. Road-building and other infrastructure must also be done in ways designed to boost productivity of existing agricultural areas rather than to expand it into new areas.

The Big Option - Adjusting Agricultural Subsidies: Governments have only so much money to spend on agriculture, and they already spend a lot. According to OECD estimates, the 21 top producing agricultural countries, producing 80% of agricultural output, devoted $486 billion to some forms of agricultural subsidies in 2012, representing wealth transfers either from taxpayers or consumers. In OECD countries, subsidies generated comprised 19% of total agricultural revenue. Subsidies are of course much lower in Africa and most of Latin America, and only some African countries have met the goal to devote 10% of public spending on agriculture. But even in Africa, spending is heavily oriented toward fertilizer subsidies, which have done some good but could often be broadened and reformed. The biggest global opportunities for CSA lie in shifting some subsidies into investments, and tweaking these subsidies to encourage greater natural resource efficiency and the full goals of CSA.

CONTRIBUTED ORAL PRESENTATIONS

11:00 How to deal with trade-offs? – A manual for policymakers

Ignaciuk Ada

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Given projected demand increases for agricultural products, there is a strong need to improve productivity on the globally limited available arable land. At the same time, agricultural activities are directly responsible for about 17 percent of global greenhouse gas (GHG) emissions. Moreover, agriculture is a major driver of land use change, land clearing and deforestation, which roughly accounts for an additional 7-14 percent of global GHG emissions. The objective of the paper, therefore, is to identify how policy can help integrate the triple gain of increased agricultural productivity, increased adaptive capacity to climate change and reduction of GHGs emission from agriculture and, depending on the case, help address and manage trade-offs between the three objectives.

To date, most of the initiatives and research related to CSA have focused on projects designed with synergies between the three objectives and little work has been done on the trade-offs associated with CSA or on the policy aspects. Additionally, so far, the CSA concept has been applied mainly to developing countries. The added value of this paper is then three-fold. First, the paper will address the trade-offs of CSA rather than focus exclusively on the synergies. Second, it will focus on the potential enabling environment for CSA, addressing the policy needs to support CSA or to manage trade-offs. Third, this paper will pay attention to the developed countries' situations. The more specific aim of this paper is to help shed some light on (i) what are the trade-offs associated with separation of policy recourse to the three challenges, (ii) whether it is possible to design policies that support the triple gain, and (iii) what are the limits to trying to address the three goals at the same time.

This paper develops a conceptual framework to analyse the synergies and trade-offs associated with targeting the triple gain. It includes both practices and policies. This framework is based on how synergies and trade-offs are conceptualised and analysed in the literature and are supported by some existing examples. A review of the academic and grey literature is also conducted to identify how mitigation, adaptation, and productivity policies can be integrated, in which cases it makes sense to do so and in which cases separated focused policy would be more efficient. Barriers to achieving synergies are also discussed.

11:15 Exploring strategic management of agricultural systems to link mitigation and adaptation to climate change

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A portfolio of agricultural practices now exists to contribute to reaching agricultural mitigation targets. At the same time, the knowledge of crop-climate interactions and potential adaptation is extensively researched. Many of the practices are based on well tested agronomic and technical know-how, with proven benefits for farmers and the environment. A suite of practices has to be used since none of the practices could provide a unique solution by itself. However, there are limitations in the process of policy development: (a) agricultural activities are based on biological processes and thus, these practices are location-specific and climate, soils and crops determine their agronomic potential; (b) since agriculture sustains rural communities, the costs and potential implementation have to be also regionally evaluated and (c) the aggregated regional potential of the combination of measures has to be defined in order to inform abatement targets and adaptation policies. This paper analyses agricultural management practices that may contribute to the abatement of greenhouse gas emissions and at the same time are well suited as adaptation strategies. The study considers their potential greenhouse gas emissions savings, their adaptation potential, their cost, and their potential implementation to reach policy targets. The evaluation framework is then applied at the farm level in NE Spain, a region that exemplifies agricultural systems in the Mediterranean region. Our research aims to contribute to shaping realistic co-benefits of the mitigation and adaptation options at regional level and therefore provide information to climate change and agricultural policies.

11:30 Nationally appropriate mitigation actions (NAMAs) for upscaling climate-smart agriculture practices

Avagyan Armine, Karttunen Kaisa, De Vit Caroline, Rioux Janie

Food and Agriculture Organisation of the United Nations (FAO), Viale delle Terme di Caracalla, 00153 Rome, Italy

Nationally appropriate mitigation actions (NAMAs) are a fast emerging vehicle for developing countries wishing to voluntarily conduct GHG reduction actions in the context of national sustainable development. Funding for NAMAs can serve as an option for up-scaling climate-smart agriculture (CSA) practices. However, until now only few agriculture and land use NAMAs have received international financial support, whereas other sectors are more advanced. In order to develop NAMAs in agriculture and land use sector, countries need specific guidance.
The objective of this paper is to present a new "NAMA tool for agriculture and land use sectors" produced by the FAO that would provide sector-specific step by step guidance for NAMA design and implementation. The tool reviews pathways for NAMA identification (*i.e.* fast track and in-depth analyses) and prioritization. It also displays required interventions to overcome barriers and presents available sources of data and funds. The tool demonstrates for example that FAOSTAT, Ex-Act and Collect Earth provide options for identification, prioritization and monitoring of mitigation actions in the agriculture and land use sectors. The fast track approach for NAMA suggests that the most efficient way to establish a NAMA is by adding climate extensions on existing development projects. The following criteria for NAMA support were identified through international requirements and different financing institutions: the level of GHG reductions, transformational change, non-carbon benefits including adaptation to climate change, full endorsement and support by the national government, as well as sustainability and replicability. Overall, based on the revised case studies, the tool demonstrates that NAMAs provides a holistic approach for CSA practices upscaling.

11:45 A business approach to poverty reduction: weather index based insurance and climate smart agriculture

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The science and development community is actively developing and promoting climate smart agricultural technologies as part of climate adaptation strategies. One such technology is drought-tolerant crop varieties. However, the seeds can be expensive and the risk of severe drought prevents many farmers from adopting them. Index insurance has been promoted as a way to help farmers manage their climate risks and, subsequently, to invest in inputs and technology that can increase their average yields and income, without worrying about suffering losses and slipping into debt. There are however, many challenges facing insurance programs, including concern about low demand, or limitations from technology, data, or infrastructure.

We report on recent case-studies that have made rapid progress in addressing these challenges, scaling to many thousands or millions of farmers. In East Africa, the Agriculture and Climate Risk Enterprise (ACRE) has recently scaled to over 200,000 through bundles with agricultural credit and improved farm inputs. In India, national index insurance programs have reached 30 million through links with agricultural credit. Finally, in Ethiopia and Senegal, the R4 Rural Resilience Initiative has scaled unsubsidized index insurance to over 20,000 poor smallholder farmers who were previously considered uninsurable, through including insurance as an integral piece of a comprehensive risk management portfolio.

There are several themes running through these 'success stories' including farmer-driven product design, the use of new technology such as satellites, strong relationships between the public and private sectors and most importantly, their ability to allow farmers to unlock productive opportunities such as CSA technologies. The rapid progress observed in recent years suggests that if implemented sensitively, index insurance has the potential to benefit smallholder farmers at a meaningful scale and allow greater adoption of climate smart agriculture.

POSTER SESSION 3

Wednesday, 18 March 2015

09:30 – 11:00

EXHIBITION HALL, LEVEL 0

L3.1 Climate adaptation and mitigation services

1. Scaling up climate information services within climate smart agriculture

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Climate information services targeted to the needs of agriculture represent an increasing area of investment by development agents. In the context of increasing climate variability under climate change, climate smart agriculture approaches require decision support tools, including climate information services that reduce the climate uncertainty inherent in farm level decision-making. Climate services can lower the risk posed to farming systems by climate shocks, and enable adoption of climate smart technologies when conditions are favorable.

We present lessons derived from a review of two national and sixteen pilot scale climate services programs across Africa and South Asia, synthesizing learning on the necessary enabling factors for producing and communicating climate information services. Our conclusions have broad relevance for development investments in more resilient agricultural production systems.

Experience demonstrates that in order to sustainably support smallholder farmers with advisory services at scale, climate services programs must address contextual factors extending beyond the capacity to produce credible information. Success factors relevant to scaling up these services include enabling institutional frameworks; platforms for capturing and integrating farmers' indigenous forecasting knowledge and feedback on services; integration of climate services with existing advisory services; and participatory methods to gauge the decision support needs of individual socioeconomic groups within communities.

2. Upscaling climate smart agriculture for food security in the Sahel region

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Sub-Saharan Africa is more and more hit by climatic extreme events. The sustainability of agriculture is a challenge in this context combined with huge demographic trends.

This work aims at simulating the impacts of the up-scaling of climate smart agriculture (CSA) practices on food security. These simulations are useful for the planning of investments in the mark of national adaptation policies.

The first step prioritizes CSA techniques thanks to a multi criteria analysis for each agroecological area, crossing data on rainfall patterns, usefulness against climatic risks of the area, soils, and annual return rates. Various scenarios of land restoration are then tested with the help of agricultural statistics (agricultural land and yields).

These scenarios allow calculating production growth and number of additional people fed on a national basis, taking into account the CILSS norm of consumption for cereals, 200 kg per year per capita. They also allow estimating the quantity of carbon stored by agro-forestry techniques. The results of such simulations in 5 countries (Benin, Burkina Faso, Niger, Senegal, Chad) show that up-scaling CSA practices on 5 to 10 % of agricultural land generates cereal surpluses enabling to face population growth.

Up-scaling costs vary from 50 to 125 millions of dollars by country on a yearly basis. Pricing cereal surpluses show annual return rates on investments between 50 and 75 %. The cost of avoided imports is also a key figure interesting for decision makers. But such an up-scaling requires additional costs focused on on-the-field stakeholders capacity building.

3. Index-based insurance for income stabilization for smallholder farms in Central Asia

Bobojonov Ihtiyor[1], Aw-Hassan Aden[2], Biradar Chandrashekar[2], Nurbekov Aziz[3]

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Climate change is one of the major challenges for agricultural producers worldwide. In Central Asian countries, climate-driven irrigation water variability is a major source of risk. Future projections indicate even further increase of production volatility in the region. Lack of financial mechanisms and high production risks are major challenges hindering investment into climate smart technologies. Agricultural insurance therefore could play an important role for reducing income volatility and create environment conducive to investment in the region. However, current premium rates in the region (*e.g.* Kazakhstan and Uzbekistan) are very high, associated with high operation and maintenance costs of the insurance companies. Insurance companies explain the high operation costs by sparse and remote location of fields and need for several visits during the vegetation period to reduce the moral hazard problem. Index-based insurance could help reducing the costs associated with field visits as well as challenges associated with information asymmetry. However, suitability of such insurance products is not tested in the region.

This study analyses the suitability of several index-based insurance tools to reduce income volatility in Central Asia. Long-term yield records were available from five case study farms in different agroecological zones (AEZs) of Central Asia. Index taken from remote sensing (NDVI, climate data) and climate stations as well as irrigation water supply are used to design insurance products for wheat growers in Central Asia. Overall analysis show that remote sensing based index insurance could serve as an important measure to reduce income volatility and create favorable environment for investment in the region.

4. Preliminary results obtained in the CLIF Project on climate change impact on fungal pathosystems

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As food security becomes an ever more pressing issue, concerns about combined climate change (CC), food security, and pesticide reduction become recurring. The network of relationships between plant diseases, the influence of CC on their dynamics, the possible shifts in disease niches and patterns, the genetic make-up of pathogen populations, and the implications these may have on agroecosystems and their performances as per the MEA criteria, including food provisioning must be addressed in a holistic approach. Plant disease epidemiology under climate change has been downplayed, compared to, *e.g.* insects and other pests. Our goal is to enhance a predictive capability for disease impact assessment and pathogen adaptation to CC for a number of annual and perennial systems. CLIF uses a two-pronged strategy based on (1) the linkage of existing research and (2) the promotion of new research projects. Existing research, initiated by individual groups will be networked, leading to interdisciplinary collaboration, geographical coverage of pathosystems, pathosystem diversity, and sharing of experimental data and models. Preliminary results were obtained on characterizing (i) climate variability useful for disease prediction (surface wetness duration, temperature within the canopy), and (ii) thermal adaptation of fungal pathogen populations (especially on stem rust of wheat and potato late blight). From a scientific point of view, our project aims at anticipating and developing predictive scenarios of the effects of CC on pathosystems, and second to develop or improve adaptation strategies to preventing or reducing disease risks. Based on stakeholder contributions, we will both analyse the CC perception from the agricultural sectors and develop a toolbox including general information on CC and pathosystems, disease models, and project outputs related to innovative adaptation strategies.

5. Modelling greenhouse gas emission under extensive livestock production systems in Kalahari South Africa

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There is little information about greenhouse gas emission and potential adaptation or mitigation measures from livestock production in Sub-Saharan Africa. This study investigates the role of additives (feed supplements) on improving livestock productivity while reducing greenhouse gas emission under extensive livestock production system in arid areas of South Africa using the FarmAC model. The following scenarios were tested: Free grazing without supplement (baseline), baseline with summer maintenance supplement (baseline summer), baseline with winter maintenance supplement where ammonium and urea were used as N source (baseline winter), base winter but ammonium and urea replaced by $CaNO_3$ as source of N. Model simulations showed that the addition of winter maintenance supplement significantly increased daily weight gain of animals while the amount of methane produced remained the same. The replacement of ammonium and urea based N sources by nitrate based N source reduced methane production significantly compared to both the baseline and baseline winter while maintaining similar productivity as the baseline winter. Model simulations also showed that the addition of urea, ammonium, and nitrate based additives did not significantly increase nitrous oxide emissions.

6. Institutionalizing crop yield forecasting for early warning in Nepal

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Nepal is one of the most vulnerable countries to climate change, facing a projected temperature rise of as high as 4.7°C by the 2090s and a 15-20 percent increase in monsoon precipitation. Different climate model projections predict increased inter- and intra-annual variations with isolated incessant rainfall events followed by prolonged droughts. Reducing the high cost of risk and uncertainty due to this climatic variability is a pivotal issue to overall food security planning and response in Nepal. Reliable and timely crop yield forecasts can thus hold relevance to informing planning and policy decisions regarding food production and early warning systems. The CCAFS Regional Agricultural Forecasting Toolbox (CRAFT), tailor-made for South Asia, can provide reliable forecasts prior to crop harvests. In this regard, with the aim of strengthening the early warning system in Nepal, the CRAFT model is being piloted in the Nepal food security monitoring system (NeKSAP), a nationwide food security monitoring system implemented by the Ministry of Agricultural Development (MoAD) with technical support from the World Food Programme (WFP), strategic guidance from the National Planning Commission (NPC) and funding from the European Union. CRAFT allows gridded spatial inputs, including soil, weather, irrigation, crop acreage and management, and genetic information in the model to predict spatially varied seasonal forecasts. The Decision Support System for Agrotechnology Transfer (DSSAT) currently serves as the crop model within CRAFT. Prior advances in crop yield forecasting pilots using CRAFT have shown encouraging results and thier performance suggests good potential for up-scaling seasonal forecasts that will allow policy-makers and planners to make evidence-based decisions to address emerging food security issues. CRAFT outputs will be incorporated into the Nepal's Government national food security bulletins, biannual crop situation updates and bi-monthly crop situation reports.

7. Analysis of extreme climate events and their impact on maize and wheat

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An extreme event is an event with a very high or low value with a low probability of occurrence. It can be characterized as a very seldom – as rare as or rarer than the 10th or 90th percentile of the observed probability density function (IPCC, 2007) – and very intense event with severe impacts on society and biophysical systems. Changing temperature and weather pattern have great influence on increasing magnitude of climate change impacts. As reported by IPCC (2007), the average global surface temperature has risen by 0.80°C in the past century and by 0.60°C in the past three decades (Hansen *et al.* 2006). The extremes of most meteorological variables, such as precipitation and temperature, are of interest because they can have tremendous impact on humans among other things through their effect on agricultural production. Thus it is crucial to characterize their behaviour statistically, as it is expected that an extreme climate event could directly impact agricultural production.

The aims of this study were (i) to characterize statistically the extreme climate events for selected locations in South Africa using both the frequentist and Bayesian approaches, and (ii) to determine the impact of the extreme climate events at these selected locations on maize and wheat production. The results showed that the extreme events fitted better in Bayesian approach than in frequentist. Furthermore, it is observed that maize and wheat yield decreased with the prevalence of the extreme climate events. However, the later results need further investigation as the analyses did not consider potential effects of, for example, the type of fertilizer used on the field.

8. Farmer rice field adaptation technology for rice-wheat cropping system in Punjab, Pakistan under future changing climate

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Climate change is a significant threat to crop production and food security in Pakistan. Its hazards would be more devastating in the future because prediction shows 2.8°C rise in maximum and 2.2°C rise in minimum temperatures for mid-century (2040-2069) in Rice-Wheat (RW) cropping systems of Punjab, Pakistan. There is an urgent need for improved climate modeling and forecasting that can provide a basis for informed decision-making and the implementation of adaptation strategies. This should include scientific knowledge of potential change in cropping systems in the future under different climate scenarios to be investigated for the implementation of adaptation strategies and planning choices that are better understood. Unless climate change trends are reversed and things return to normal, agriculture would be the most seriously impacted sector. Crop Growth and Global Circulation Model are helpful tools to assess the climate change impact and can also provide a basis for informed decision support and development of adaptation strategies for the stakeholders. The proposed study was planned to ensure food security by quantifying the future climate variability and adapting the climate resilient technology for fine rice. Crop growth models (DSSAT & APSIM) were calibrated and evaluated on experimental field data to develop the robust genetic coefficients. Models were validated using farmers' field (155) data of five districts in RW cropping systems. A close relationship was observed between farmer's data and simulated fine rice yield with good statistical indices such as Root Mean Square Error (RMSE) 409 kg ha^{-1} and 440 kg ha^{-1} with d-index (0.80 and 0.78) for DSSAT and APSIM, respectively. Climate change impact was quantified with crop models using baseline (1981-2010) and future climate data of five General Circulation Models (CCSM4, GFDL, HadGEM, MIROC5, and MPI-ESM) for the mid-century (2014-2069). Mean yield reduction for DSSAT ranged between 8 to 30 % while for APSIM yield reduction was 14 to 19 % with five GCMs. Adaptation technology was developed to cope with the drastic impacts of the changing climate. To achieve high productivity and meet the need of a growing population, it would be required to increase the planting density, fertilizer use and reduce the irrigation amount up to 15 % each, which was considered as one of the adaptation strategy for promising cultivars with greater potential. Due to high temperature the cropping seasons would be affected and 5 days earlier transplanting of nursery would be recommended for mid-century. These strategies have a significant impact in reducing the vulnerabilities related to the changing climate with 33 % improvement in rice yield, having a great potential to sustain food security in Rice-Wheat cropping systems and representing a big step towards climate smart agriculture.

9. Are autonomous adaptation help to improve resilience of farmers? Insights from local scale analysis from South India

Dhanya Praveen, Ramachandran Andimuthu, Palanivelu Kandasamy

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The impact of changing climate patterns in the decades to come will be felt by all economic sectors across the globe. The latest AR5 report also corroborates that Climate change is expected to cause substantial crop reductions in tropical regions in general and in developing countries like India in particular. Farmers in the study area face considerable weather-induced risks in the form of droughts, cyclonic storms and outbreaks of pests and diseases, which reduce their income stability. Warming and extreme climate events are predicted to intensify by RegCM 4 model under the RCP 4.5 pathways for North East Tamil Nadu. The mean maximum and minimum temperature are predicted to rise by 2.3°C and 2.5°C respectively and high variability in precipitation pattern is also predicted by the end of this 21st century. The case study using rapid rural appraisals reveals that farmers in this area are striving to combat these challenges by shifting their traditional crop varieties to less water intensive crops like groundnuts, Jasmine, Cluster beans and sesame etc. as an autonomous adaptation mechanism. Some of the farming communities have started renovating community ponds and adopting micro irrigation facilities as well. However a comprehensive and integrated planned adaptation is the need of the hour, blending the latest scientific and local knowhow and site-specific needs. The latest climate information should be disseminated to the farming community level to create a resilient, climate-smart 'Farms and Farmers of the Future'.

10. Developing web services to foster the adaptation of agriculture, forestry and water management to climate change

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The adaptation to climate change of agriculture and forestry as well as water management require tools to predict the effect of multiple scenarios combining agronomy, forestry, water management and climatic components in any physical environment, in order to anticipate negative effects of climate change and to choose the most relevant strategies anywhere. A project is currently developed for building integrated tools and delivering services, encouraging midterm and strategic adaptation over France, by coupling agronomy, forestry and hydrology models. This project presents two main aspects: 1) an analysis of stakeholders demands, which has already shown that different spatial levels (territory, hydrological basin and whole France) would have to be considered, that demands are multiple and multiform, declined according to different levels of information (general information on the effect of climate change on agriculture and forestry, site vs. crop rotation modeling, up to totally distributed spatiotemporal agro-hydrologic modeling including economic dimensions); 2) an inventory of the currently available databases and models (climate, soil, crop and hydrology) and an analysis on how to couple them and overcome sectorial vision. The objective of a first step is to elaborate the specifications of a detailed integrated model, taking into account the demands of the stakeholders. This project is developed by INRA and partners (Irstea, BRGM, CEA, CNRS, Universities, Météo France, …) under the umbrella of Allenvi, the National Research Alliance for the Environment.

11. Evaluation of GHGs, C stocks and yields from European cropping and pasture systems under two climate change scenarios

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Simulation modelling proves to be an effective tool in the evaluation of the impacts of climate change on agricultural production systems. For this purpose the AnimalChange project (FP7) -Task 5.1- presented here, aims to employ the most suitable simulation approaches to project the impacts of climate change in the agro-ecosystem at regional scale, in order to assess prospective GHG emissions, carbon stocks and crop, livestock and grassland production. The pasture biogeochemical model PaSim and the crop model CERES-EGC were used to evaluate the agro-ecosystem under climate change scenarios at European scale. For this purpose meteorological, soil and management spatialised data applied to a 0.25° × 0.25° latitude-longitude grid were used. Two climate change scenarios were employed on the basis of anthropogenic perturbation of the climate system of +4.5 and +8.5 W m^{-2} to year 2100, IPPC RCP 4.5 and RCP 8.5 scenarios, respectively. Soil representative characteristics for each grid cell were provided by the European Soil Database. Crop type and management data were obtained by identifying the main crop rotations for each mesh of the grid, starting from a 1km × 1km resolution database provided by the GHG-Europe project (FP7). Plant sowing and fertilisation dates were chosen yearly on the basis of thermal and pluviometric data. Finally, grassland management (cutting date, amount and type of fertilisation), animal management and stocking densities data were obtained from the CAPRI modelling system (Common Agricultural Policy Regionalised Impact). The results allowed an overall assessment of (i) the temporal evolution of N_2O and CO_2 over Europe (ii) soil carbon stocks and (iii) crop, grassland and animal production of the main productive areas related to livestock. Furthermore, a change in the sowing dates and in the cycle duration of the main cultivated crops, as well as the need to introduce crop irrigation in some European areas has been observed.

This study was financed by AnimalChange FP7 project.

12. Food security and climate change: a vulnerability analysis of agricultural livelihoods in Central America

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Central America is the tropical region where the biggest changes in climate are expected. The impact of climate change on food security will depend not only on the capacity to produce different crops but also the sensitivity and adaptability of social-agroecological systems. We performed a vulnerability analysis of agricultural livelihoods of municipalities of the Central American countries in order to define priority areas and strategies to support planning for climate change adaptation and CSA in each. We assumed as agricultural livelihoods the current combinations of priority crops, and exposure as the expected variation in the distribution of suitable areas for these crops in 2030 under high emissions scenarios. Exposure was calculated using ecological niche models. We used the economically active agricultural population as an indicator of sensitivity, and build an index of adaptive capacity using indicators weighted by scientists and decision makers to explore potential bottlenecks in the adaptation process through multivariate analysis. The results show that temperature increases and changes in precipitation patterns expected by 2030 will cause changes in the distribution of areas that support rural food security. Half of the municipalities lost productive capacity because they combine high exposure and sensitive crops. Among those who gain productive capacity are those with a high proportion of less sensitive crops and those at higher elevations, where a possible increase of agricultural potential nevertheless conflicts with other land uses. Decisive factors in defining groups of municipalities with different adaptive capacity within each country includes the diversification of production, satisfaction of basic needs and access to resources for innovation.

This research was conducted with the support of CCAFS and REGATTA-UNEP.

13. Impact of climate change on household income and poverty levels: empirical evidence from South Asia

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The current study is based on a comprehensive cross-sectional dataset collected from three South Asian countries *i.e.* India, Nepal and Bangladesh. More than 2500 farmers were interviewed by using a detailed comprehensive questionnaire. South Asian region is the most vulnerable to climate changes. The current paper analyses the impact of high temperature, less rainfall and strong winds on the yields of wheat, paddy and maize. In addition, this study also analyses the overall impact of the climate change on household income, food security and poverty levels. The empirical results indicated that due to climate change the yield of wheat, paddy and maize considerably declined. In addition the household income and food security levels are also reduced while the poverty levels have increased. The current study has important policy implications, showing that awareness among the farming community needs to be created besides familiarizing with different coping strategies to combat the effects of climatic challenges.

14. Irrigated rice practices changes in the Senegal River Valley according to climate and constraints evolutions

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More and more irrigated rice farms of the Senegal River Valley (SRV) no longer respect the sowing periods promoted in the 90s to reduce sterility risks due to extreme temperatures. This study aims at understanding that reality and assessing whether new sowing periods must be defined. Combining focus-groups and surveys, climate analysis, field experiments and modeling work with RIDEV model, it addresses the evolution of cropping practices and their constraints, farmers' climate perception, climate evolution and its consequences on rice development and sowing periods in the SRV.
Data analysis shows rainfalls and temperature increases, and particularly a significant increase between the present decade and the 1950-1980 period which was considered for the establishment of the recommended sowing windows (+1°C to +2°C on monthly averages for Podor), with less extreme cold temperatures and more extreme hot ones. Farmers are very aware about recent climate evolution, with respectively 94% and 72% of them saying that rainfall and temperature patterns have changed. More precisely they commented that "the cold period shifted by about one month, from "October/November – February/March" to "November – March/April". Nevertheless the majority considers that the recommended sowing periods are still pertinent and explain that late sowings are due to delayed access to tractors, inputs and credits. Only few ones (5 %) intentionally sow late, considering there is no longer a danger in doing that. However, in 2011 farmers who sown later got very bad yield and farmers explain that "because the cold arrived earlier as it happened in the past". Yet, while farmer's comments appear coherent with climate data, up to now we can't totally confirm them by crop modelling since we still have difficulties in the simulation of the sterility despite recent model improvements. Additional work is required to reach a conclusion.

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15. Towards high resolution adaptation strategies to climate variability and change

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In agricultural systems, spatial-temporal climate variations strongly influence crop growth and productivity. These variations along with internal-external factors play decisive roles in plot- to farm-level decision making and adaptation process. 21st century climate change consequently introduces new dynamics and challenges, where robust adaptation strategies to short-term climate variations and long-term climate changes become essential. Within this perspective, scenario- and system-based approaches have emerged as key concepts. This study draws on both approaches, all towards constructing high resolution adaptation strategies to climate variability and change. Our study takes place in the Coteaux du Layon and Saumur Champigny, two regulated wine growing regions situated in the middle Loire Valley, France. These two regions are very different in terms of environmental conditions, varietal materiel and cultural practices. The methodological framework used in this study followed several steps. Firstly, both study areas were equipped with climatic and agronomic measurements at vineyard-level scales. From here, the local climate and vine behaviour were characterized according to topographic features, soil properties and cultural practices. Secondly, wine growers' perceptions, vulnerability and adaptation to climate variability and change were assessed through semi-directed interviews. And finally, future climate trends were evaluated from a regional climate model. From this knowledge base, vine behaviour and viticultural practices and decision making were modelled, depending on current and future spatial-temporal environmental constraints. This modelling approach is based on combining an object-oriented geodatabase, a geographic information system and a multi-agent modelling system. Modelling farming practices and their interaction with the local environment permitted to construct high resolution adaptation strategies to climate variability and change.

16. AgMIP's transdisciplinary approach to regional integrated assessment of climate impact, vulnerability & adaptation

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This poster presents economic impact results (adoption/adaptation, production, income, poverty) from regional teams in Sub-Saharan Africa and South Asia that are part of the Agricultural Model Intercomparison and Improvement Project (AgMIP). All of the teams are utilizing the new integrated assessment methodology developed by AgMIP. This approach represents a departure from approaches in the literature in several dimensions. First, the approach is based on the analysis of agricultural systems (not individual crops) and is inherently trans-disciplinary: it is based on a deep collaboration among a team of climate scientists, agricultural scientists and economists to design and implement regional integrated assessments of agricultural systems. Second, in contrast to previous approaches that have imposed future climate on models based on current socio-economic conditions, this approach combines bio-physical and economic models with a new type of pathway analysis (Representative Agricultural Pathways) to parameterize models consistent with a plausible future world in which climate change would be occurring. Third, adaptation packages for the agricultural systems in a region are designed by the research team with a level of detail that is useful to decision makers, such as research administrators and donors, who are making agricultural R&D investment decisions. Finally, the approach represents not only "mean" impact the distribution of impacts among farm populations. The poster summarizes the impact assessment and adaptation analysis results, comparing and contrasting among study areas, and highlighting the role of the Representative Agricultural Pathways in climate impact assessment.

17. Representative agricultural pathways for integrated assessment of climate change, vulnerability & adaptation impacts

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The global change research community has recognized that new pathway and scenario concepts are needed to implement impact and vulnerability assessment that is logically consistent across local, regional and global scales (Moss *et al.* Science 2010). For global climate models, Representative Concentration Pathways (RCPs) have been developed; for impact and vulnerability assessment, new socio-economic pathway and scenario concepts have also been developed (Kriegler *et al.* 2012; van Vuuren *et al.* 2012, Global Env Change), with leadership from the Integrated Assessment Modeling Consortium (IAMC). One of the goals of these new developments is for them to be linked to sector-specific and regional pathways and scenarios. A major effort in this direction is the development of global and regional Representative Agricultural Pathways (RAPs), with leadership from the Agricultural Model Inter-comparison and Improvement Project (AgMIP). This poster will provide an overview of the RAPs concept and methods for their development within the integrated assessment framework developed by AgMIP and then illustrate their development and use by the AgMIP Regional Research Teams in Sub-Saharan Africa and South Asia.

18. Trends in dry spell and extreme rainfall events and significance for alternative and sustainable agriculture in Malawi

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The objective of this work was to identify the spatial and temporal changes in rainfall at very small scales, which will provide local information on rainfall variability that is not usually extracted from aggregated spatial mean as a proposition to situating alternative and sustainable land management practices. A bias-corrected meteorological dataset on the maize-growing season between 1961 and 2007 was used to analyse trends in dry spell and extreme rainfall events by non-parametric Mann–Kendall technique. A set of indices were derived from the daily rainfall time series for three sites; Lilongwe, Dedza and Balaka, representing broad geographical and climatological zones in Malawi. In Central Malawi, the high altitude zone of Dedza and mid-altitude plateau of Lilongwe south showed positive and significant trend for extreme rainfall events along with negative and significant trends for the number of rain days. These trends in the latter location were coupled with negative and significant trend in total seasonal rainfall. Whereas the trends for dry days or dry spells were not significant, the contribution of dry spell events of greater duration than 5 days was noted across the three zones. The results of this study showed that the drier location, Balaka, with the highest number of dry days, was not necessarily the most sensitive to rainfall fluctuations. Overall, the results are in contrast to assumption that the mark of climate on the year-to-year variability is more obvious in the driest locations than in the wet locations and thus where sustainable land management practices need to be promoted. This study further highlights the need to evaluate the most salient rainfall parameters indicative of climate variability that will assist in seasonal forecasting and risk management at the local level.

19. Analysing the quality and reconstructing daily weather data for crop growth simulation models

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Crop simulation models can be used to estimate the impact of current and future climate on crop yields and food security. For this, long-term historical daily weather data are required. The accuracy of the simulated yields is dependent upon the quality of the weather data. For many regions available daily weather data show irregularities or missing values. The objective of this study is to develop a methodology for analysing errors and reconstruct missing values on weather data based on statistical functions in R.3.0.0. This approach is illustrated for Monze Farmer Training Centre in Zambia. Weather data analysed were minimum and maximum air temperature, precipitation and solar radiation. Visual data exploration allowed initial identification of outliers and systematic errors due to sensor or transcription problems. For minimum and maximum temperature and rainfall outlier detection, thresholds were defined for different times in a year. The singular spectrum analysis (SSA) method was used to fill data gaps resulting from removal of the anomalies. By detecting the general signal trend, the SSA extrapolates it to the period of missing data, allowing filling the data gaps. Visual data exploration showed signs of repeated coping and pasting of the solar radiation data. The Mountain Climate Simulator (MT-CLIM) was used to estimate solar radiation using daily maximum temperature, maximum temperature and precipitation. Comparison of the observed and simulated solar radiation showed a 'good' RMSE of 19.7%. Our methodology, based on statistical and graphical approaches improves weather data quality for long term series and it will increase the ability of researchers in sub-Saharan Africa, and elsewhere, to make the best use of local weather data, although with irregularities or missing values, for cropping systems modelling.

20. Gender assessment of climate change adaptation strategies in south-western Nigeria

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Background Aims: Adaptation is the ability of human systems to adapt to and cope with change and further states that adaptation depends on. Gender assessment play a part in influencing which resource women or men can access and play a major part in determining capacity to cope with the outcomes of climate change. This paper assessed the adaptation strategies by gender in south-western Nigeria.
Materials and Method: Primary and secondary data were collected through a well-structured questionnaire. This structured questionnaire was developed to obtain relevant information on the activities of governmental and non-governmental organizations relating to climatic change and gender. Purposive random sampling technique was used to select organizations involved in gender and climatic change activities. Information on the activities of the organizations was sought through the survey questionnaire.
Results and discussion: Women are victims of climate change and are effective change agents in mitigation and adaptation. Women also perform various tasks such as water supply and energy. They are more vulnerable with less access to resources and decision making. Women were found to be willing and able to play a key role in developing and implementing adaptation and mitigation strategies. They are involved in climate change decision making at the local and professional levels
Conclusion: Women need to be given a voice in resource mobilization and decision making. Climate change and gender challenges need to be taken holistically and be on locality-specific interventions at the local and national levels. Group participation at the local, national and global levels should be encouraged Training at all levels is therefore necessary to prevent major disasters.

21. Sensitivity analysis for climate change impacts, adaptation and mitigation projection with pasture models

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The development of climate adaptation services requires an improved accuracy in model projections for climate change impacts on pastures. Moreover, changes in grassland management need to be tested in terms of their adaptation and mitigation potential. Within AgMIP (Agricultural Model Intercomparison and Improvement Project), based on the C3MP protocol for crops, we explore climate change impacts on future greenhouse gas emissions and removals in temperate grassland systems. Site calibrated models are used to provide projections under probabilistic climate change scenarios, which are defined by a combination of air temperature, precipitation and atmospheric CO_2 changes. This design provides a test of yield, greenhouse gas emissions (N_2O and CH_4) and C sequestration sensitivity to climate change drivers. Moreover, changes in animal stocking density and in grazing *vs*. cutting are explored to test potential mitigation and adaptation options. This integrated approach has been tested for 12 models applied to 19 grassland sites over three continents and is seen as a pre-requisite for the use of models in the development of climate adaptation and mitigation services for grazing livestock.

22. Biochar: an environment friendly approach to mitigate climate change

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Biochar, a pyrolysis product of organic residues has received wide attention as an amendment for agricultural soils to absorb pollutants in soil to improve soil fertility and crop productivity, sequester CO_2 and reduce greenhouse gas (GHG) emissions to mitigate climate change impact. Little information exists in Pakistan on the short- and longer-term effects of biochar on soil microbial communities and enzyme activities, relative to other organic amendments such as manure, while energy production from bioenergy crops may considerably reduce GHG emissions through replacement of fossil fuels. Biochar may decrease the net climate forcing of bioenergy crop production although this has not yet been assessed under field conditions. Significant reduction of soil nitrous oxide (N_2O) and carbon dioxide (CO_2) emissions has been observed in short-term laboratory incubations by a number of researchers; however, evidence from long-term field trials has been conflicting. Present study investigated whether biochar amendment could suppress soil GHG emissions under field and controlled conditions. In a field experiment, biochar amendment suppressed soil CO_2 emissions by 33%. Under controlled temperature and equalised gravimetric water content in the laboratory, biochar amendment suppressed soil CO_2 emissions by 53% and net soil CO_2 eq. emissions by 55%. Research findings demonstrate that biochar amendment has the potential to suppress net soil CO_2 eq. emissions in bioenergy crop systems for up to 24 months after addition, mainly through reduced CO_2 emissions. We conclude that hardwood biochar has the potential to improve the GHG balance of bioenergy crops through reductions in net soil CO_2 eq. emissions. The prospect of biochar utilization is promising, as biochars may be customized for specific environmental applications.

23. Response of fine rice cultivars to various transplanting dates under climate change scenario of Pakistan

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Rice (*Oryza Sativa L.*) is the second largest food crop of Pakistan which adds 4.4 percent in agriculture and 0.9 percent in GDP. In order to assess the Agro-Management practices for better growth and yield of fine Rice cultivars under Climate Smart Agriculture Program, an experiment was conducted at the University of Agriculture, Faisalabad Pakistan where three transplantation dates (TD1= 10 July, TD2= 25 July, TD3= 9 August) and three cultivars (V1= Shaheen Basmati, V2= Super Basmati, and V3= Basmati 515) were studied using Crop Models. Analysis of data reveals that transplanting dates and different rice cultivars significantly affected the yield and yield-related factors like number of grains per panicle, thousand grain weight (g), number of productive tillers (m^{-2}), grain yield (t ha^{-1}) and other related traits significantly, and first transplantation date proved to be the best for obtaining higher grain yield of fine rice. Under Semi-Arid conditions of Faisalabad, fine rice cultivar Basmati 515 proves best with better yield if transplanted within the first two weeks of July but when delayed, the grain yield is severely affected due to shortening of growing season length. Crop model also provided good estimations of grain yield from independent experiments. Simulations showed that recent climatic changes could have caused a decrease in rice yield. Model also facilitated the selection of the best transplanting date. In seasonal analysis, the crop was found to be sensitive to changes in carbon dioxide (CO_2) and temperature. Future climate change scenario analysis showed total dry matter (TDM) will increase with rise in CO_2 concentration and grain yield was also significantly affected by the increase in CO_2 concentration from 396 ppm to 550 ppm. Moreover, rise in temperature will shorten crop duration from planting to physiological maturity (with difference of almost 16 days in 2020's and 25 days in 2050's, respectively), consequently decreasing the yield as compared to the current situation. Standardization of crop production technology through crop growth models should be initiated. Development of site-specific adaptation strategies is necessary to enhance agricultural productivity under changing climate scenarios.

24. Climate smart services: case studies in Senegal, Burkina, and Colombia

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The transition to climate smart farming systems requires the definition of new climate information, modeling tools for a systemic assessment of performances of farming systems under pillars of CSA, and new advice services. Our communication is based on different case studies conducted in Senegal, Burkina Faso, and Colombia. In the case study in Senegal, local climate forecasts were produced for small farmers linking local (bio-indicators) and scientific (local climate forecast) knowledge. This project showed that the use of the two kinds of knowledge and of an innovative and participative strategy to work with a diversity of partners and next users were key to produce and spread relevant information to support decision making of smallholders farmers in a context of climate uncertainty. The case study in Burkina Faso was based on the use of a whole farm model with three main types of farmers found in the Sudanian area. We show how the use of the model permitted a systemic assessment of the effect of introducing a CSA practice on productivity, variation of income or use of mineral fertilizers taking into account the specific management strategies of the different types of farmers. The case study conducted in contrasted area of Colombia was based on investigations made with farmers and advisers from a national organization of cereal farmers in order to assess their perception and needs in terms of information and services in face of climate change. We share the contrasted visions of farmers on climate change and show how it is linked to their specific demand in terms of information and services. For advisers we show the need of renewing their current top-down modality of interaction with farmers. We draw lessons in terms of how to link the approaches developed in each case study for integrated and innovative CSA services.

25. Climate-smart cropping patterns on exposed coasts and near-coastal uplands, central Vietnam

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Vietnam's long coastal line and steep topography makes it among the countries ranked as most vulnerable to climate change. In response to extreme weather events such as cold spells, droughts, floods storms and typhoons and increasingly variable weather patterns, farmers have been forced to alter farming calendars, reducing the cropping seasons and altering crop combinations. The Farmers Association together with World Agroforestry Centre have mapped and evaluated the suitability of existing tree-crop systems in twelve villages along a transect from the coast to the uplands, using farmers' criteria to come up with a climate risk map and adapted land-use planning options.

From the coast a series of vertical and lateral multistory tree-crop combinations (agroforestry systems) are showing promising evidence of reducing wind speeds, lodging of rice, drifting sand dunes, salt particle deposits on plants. To further enhance the livelihoods of farmers who have been forced to shift cropping patterns, the Farmers' Association is testing the performance of new crops such as asparagus and sweet potato. The poster presents an evaluation of a series of climate-smart initiatives, in terms of their performance for providing sustained livelihoods, synergies between adaptive strategies and mitigation potential.

26. Adoption of climatic challenges mitigating strategies at farm level: empirical evidence from South Asia

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The climatic conditions are changing rapidly globally. The south Asian region is the most vulnerable to these climatic changes. The current study is based on comprehensive farm level data set collected from three south Asian countries *i.e.* India, Bangladesh and Nepal. During the survey, more than 12000 farming households were interviewed in India, Nepal and Bangladesh. Comprehensive questionnaire was employed for the data collection. The data was analysed by employing a number of econometric models. The multivariate probit model was estimated to see the joint impact of the climatic coping strategies adopted by the farmers at farm level. The propensity score matching approach was employed to correct for potential sample selection biased that may arise due to the differences between the households vulnerable to the climatic changes and household not vulnerable to climatic changes. The empirical results indicated that farmers at farm level have adopted a number of climate mitigating strategies like adjustment in the sowing and harvesting time, adoption of the drought resistant varieties, shifting to other crops etc. The empirical results indicate that the awareness among the farming community is very important and that that has encouraged the adoption of different climate mitigating strategies and the households have maintained their income levels and have less poverty levels. The major climatic challenges are the rise in the temperatures, erratic rainfalls, shift in the sowing and harvesting times etc.

27. Can ecosystem-based adaptation help smallholder farmers adapt to climate change?

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Smallholder farmers are critically important for global food security and global land use, as they represent 80% of the world's farmers, provide an estimated 80% of food consumed in developing countries and occupy much of the world's farmland. However, unless adaptation measures are quickly put in place, climate change will have significant impacts on smallholder agricultural production and livelihoods, with important ramifications for global food security. Ecosystem-based Adaptation (defined as the use of ecosystem services and biodiversity as part of an overall adaptation strategy to help people adapt to the effects of climate change) is one approach that could help smallholder farmers adapt to climate change, as part of a broader adaptation strategy. To date, there is little information on what Ecosystem-based Adaptation (EbA) options are feasible for smallholder farmers, how effective these options are, and what the opportunities and constraints are for scaling up its use. Using a combination of detailed household surveys, field characterizations and expert interviews from three countries (Costa Rica, Guatemala and Honduras), we identify EbA options that are appropriate for smallholder coffee and maize/bean farmers in Central America, examine the relative advantages and drawbacks of different EbA practices in coffee and basic grain smallholder farming systems, and compare the effectiveness of different EbA approaches for reducing farmer vulnerability to extreme weather events. We also examine the key technical, policy and financial constraints that currently prevent broad scale adoption of EbA practices across the region. Our study highlights that many smallholder coffee and bean/maize farmers in Central America are already adopting EbA practices (such as shade coffee, soil conservation practices, live fences and other agroforestry practices) and are generally aware of the relative benefits or drawbacks of different practices, but that the lack of extension services, financial incentives and policies favouring the use of EbA currently constrain broad-scale adoption.

28. ITK Vigne, a decision-support tool to adapt wine production to climate change, with or without irrigation

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Climate change is an important challenge for most wine producing countries, since wine quality is closely linked to terroir, an interaction between soil, climate and training method. Hence a change in climate should induce a change in viticultural techniques, if one wants to keep the typicity of his appellation wines. In the Mediterranean region, the evolution towards warmer and drier summers has a strong and generally unfavourable influence on vineyard productivity (*i.e.*: yield and quality). Optimal vine water status dynamics have been therefore defined to produce distinctive wine profiles. However, the latter approach is rarely implemented in practice, since classical methods to measure grapevine water status are either too tedious or too expensive to be implemented on a large scale.

To overcome those limits, a model-based decision support system (DSS), named iTKVigne, has been developed by a consortium led by ITK Company. The models included in this DSS were specifically adapted from former work done by INRA and CIRAD, and have been tested in the field from 2009 to 2013. After an initial calibration, this DSS has proven to be able to provide a very satisfactory estimation of pre-dawn water potential according to the soil, climate and vineyard training method at significantly lower cost than classical techniques. Unlike physical water status measurements, iTKVigne does not only allow a more accurate and water saving irrigation (irrigation quantities are generally reduced by about 15% when compared to current irrigation practices), it also allows adapting the training method according to the desired production objective, for winegrowers who cannot or do not want to irrigate. It may also be used as a tool to forecast on a production objective basis the future water requirements of new irrigation perimeters.

ITKVigne is an output of Disp'eau, a collaborative project funded by the French "Fonds Unique Interministériel", the Languedoc-Roussillon region, and FEDER.

29. QUICKScan: A decision support tool for a participatory exploration of land use mitigation and adaptation options

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Climate smart agriculture requires the development and use of appropriate decision support tools (DST), that allow assess and explore ecosystem services and evaluate options at different levels and scales. DST should include: a.) An approach to incorporate stakeholder perspectives and needs, b.) A toolbox to integrate different data/knowledge (*e.g.* statistics, spatial data, local knowledge) and functionalities (*e.g.* workflows, up-scaling/out-scaling) that allow explore options and c.) A participatory process to ensure stakeholders definition, iteration and exchange for appropriate information production. The goal of this paper is to present results and insight on QUICKScan uses, to assess and explore mitigation and adaptation options for agriculture systems and farm management (at local and national scales), between different policy contexts (at national and regional scales). It includes the evaluation and analysis of main impacts and effects of options and trade-offs and synergies of different policies, on ecosystem and climate services. QUICKScan provides appropriate framework and interface with functionalities, for a participatory exploration, interaction and iteration in short time (1-2 day workshop), allowing stakeholders to play with choices, assess impacts and effects of different alternatives and facilitate the marrying of quantitative analysis and qualitative judgments in support of transparent and flexible decisions to be taken. The QUICKScan applications and results presented, besides exploring agriculture and farm management options, land use alternatives and identifying hotspot areas and ecosystem services, show how DST can ease to close the gap between scientific tools offer and decision making uses demand. So, the results and insight are based on different uses and applications developed with a range of stakeholders to explore, for instance, ecosystem integrity as mitigation option for land use change in the Amazonia, agriculture production systems as adaptation options for climate change in Central America and Green infrastructures as land use option for ecosystem services enhancement in Europe.

30. Gender specific perceptions and adoption of the climate-smart Push-pull technology in eastern Africa

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The performance of the agricultural sector in many developing countries has been rated as below average and the most hit are the staple cereal crops whose productivity is limited by both biotic and abiotic factors. The African witch weed (striga), stemborers, poor soil fertility and climate change are among the main factors attributed to poor productivity. Furthermore, the underperformance of the agricultural sector has in part been attributed to inability of women to access to productive resources, yet they represent a crucial resource in agriculture and the rural economy through their roles as farmers and entrepreneurs. This study evaluated gender-specific perception and the adoption extent of a climate-smart push-pull technology for controlling stemborers, striga weed and improving soil fertility in drier agro-ecologies where the constraints are quickly spreading. The findings show significant gender variations in farmers' perception on farming constraints and on beneficial technology attributes. A higher percentage of women rated low cereal yields (98.2%), poor soil fertility (96.3%) and limited land (26.3%) as major constraints compared to men; and also more women highly rated the beneficial attributes of the technology; *e.g.* 97.3% of the women vs. 94.6% of men cited increased cereal production; 97.2% women vs. 92.4% of men cited decline in striga weed; 95.9% of women vs. 90% of men cited an increase in soil fertility; 94.1% of women vs. 91.3% of men cited an increase in fodder production and 82.3% of women vs. 66.5% of men cited an increase in cereal and fodder production even with drought. The understanding of the gender differences and perceived technology attributes will enhance further adoption via tailored dissemination strategies.

31. Critical issues for the design and operation of business models for technological CSA innovations

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Technological innovations are likely to play a key role in the development of Climate Smart Agriculture (CSA) in Europe. However, the adoption and diffusion of technological CSA innovations are subject to a range of socio-economic barriers. Business model approaches are receiving increasing attention in sustainability related transitions, due to their criticality for the successful diffusion of innovations; yet exploration of this perspective is limited in relation to CSA. The aim of this paper is to identify critical issues for Business Models for CSA (BMfCSA), and their role in enhancing the adoption and diffusion of technological CSA innovations. To achieve this aim, we first constructed a theoretical framework of critical issues for Business Models for CSA technologies (BMfCSA), based on a review of the 'Business Models for Sustainable Development' (BMfSD) literature. This framework was used to identify critical issues for BMfCSA. Data was collected through semi-structured interviews (n = 30) with key informants (technology providers, farmers and farmer associations, industry) involved in the development and adoption of technological CSA innovations in the Netherlands, France, Switzerland and Italy. The data covered critical issues for business models for CSA and the market needs of technology providers and users to address these critical issues. The data was then applied to the BMfSD framework to identify critical issues for BMfCSA. Preliminary results identify that current BMfCSA technologies are deficient with regards to their value propositions, customer relationships, key resources, channels, revenue streams and cost structures. Using the identified critical issues, the paper develops potential services that are designed to respond to the market needs of CSA technology providers and drive the solution of the critical issues for BMfCSA, to boost the diffusion of CSA technologies in the European agricultural sector.

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32. Building resilience to climate change: the role of robust methods

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Research can support farmers to enlarge their portfolio of strategies and adaptation options, both existing and new, to manage increasing climate risks. However, research should not only explore impacts and adaptation options but go one step further: appraising adaptations options to weigh up the costs vs. benefits. In our work, we first gather potential impacts of climate change in the agricultural sector in Europe and present an extensive range of adaptation options to address these. Second, we classify the adaptation options according to whether they would be implemented reactively or in anticipation of climate changes. We conclude that a large part of adaptation measures in the agricultural sector will be reactive, as many management decisions are made over short decision horizons, thus adaptation would not need to begin occurring until the climate clearly is changing in a particular way. Economic appraisal in the context of reactive adaptation can occur through standard cost-benefit analysis. Anticipatory adaptation, *i.e.* implementing adaptation options before the climate change occurs is needed for capital-intensive investments with a long lifetime. For this, the inherent uncertainty about future climate change impacts and potential avoided damages makes meaningful appraisal challenging. For anticipatory adaptation measures, we therefore suggest the use of so-called 'robust decision-making methods' for appraisal including robust decision making (RDM), real option analysis and portfolio analysis. Robust approaches deliver adaptation goals by selecting projects that meet their purpose across a variety of plausible futures and are thus particularly suited for deep uncertainty. Generally, robust approaches do not assume a single climate forecast but integrate a wide range of climate scenarios. We provide concrete examples on how these could be accomplished technically as guidance to decision-makers in the agricultural sector.

33. Co-design of scenarios and adaptation strategies to climate change in the highlands of Madagascar

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In Madagascar, rice is the major staple food. The availability of fresh water for irrigation and the temperature at some plant stages are critical variables for the farmers' choice of cropping systems and their self-sufficiency in rice. Climate change is expected to affect the rainy season and temperature, potentially impacting the crop yields. Participatory research and development take into account local knowledge and innovations to support the co-development of local adaptation strategies. We propose a methodological framework for the participatory development of scenarios with farmers and stakeholders to identify and evaluate possible adaptation strategies to climate and other global and local changes. The idea is to understand the farmers' perceptions to risk and their way to cope with technical change. First, we conducted farmers' interviews to understand the current systems and constraints to create a farm typology. Then focus groups were held to identify the main drivers of change and develop, in full partnership with local population, four scenarios related to climate change, infrastructure, access to market and labour availability. These scenarios were then applied in the context of four farms selected to represent each significant farm of the typology. For each scenario, some adaptation strategies (*e.g.* new varieties, crop management, diversification of production, water control in the valley) were selected and further assessed with the farmers using a farm model to simulate the impacts on relevant indicators. This methodological approach showed that combining scenarios and models in a participatory approach effectively tackles the issue of climate change impact and possible mitigation strategies rooting solutions linked to the local social, economic and resource constraints. This could lead to further local development policies.

34. Climate change adaptation in the dry zone of Honduras: learning by doing

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Zamorano University is an agricultural university in the dry corridor of southern Honduras. More than 3,000 hectares of land on its campus are used for research, conservation, production and education. During the last years it has become an important location for research and teaching on climate change adaptation and mitigation strategies. Besides offering a solid academic educational program, Zamorano´s institutional mission also incorporates extension activities to enable people to improve their lives and communities through partnerships that put experience and research knowledge to work. Zamorano University is best known for its "Learning-by-doing" approach to education and capacity building. This approach allows students and/or farmers to integrate knowledge and resolve problems in different professional environments that reflect real world situations. With the support of USAID, Zamorano established in 2012 a learning-by-doing module called "Crop Management against Climate Change". This module teaches students how to develop resilient agricultural systems using rational and affordable strategies, in such a way that ecosystem functions and services can be maintained and livelihoods can be protected. Technologies included in the module are mulching, terrace cultivation, drip irrigation, water harvesting, integrated pest management and permaculture. In the module we work with basic food crops such as maize and beans, as well as cattle and horticulture. During the last two years, more than 350 students from 18 countries from Latin America have been trained in the subject matter and 12 undergraduate projects have been completed on crop management and climate change. The module has been successfully extended to the field in Honduras, El Salvador and Nicaragua. With the support of the local organizations and Zamorano´s extension service, demonstration fields were set up in each of the three countries and more than 80 farmers were trained in the application of conservation technologies to increase the resilience of their production system against climate change.

35. From plot to regional scale, spatial modelling of crop systems using interaction graphs

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Developing a climate-smart agriculture towards the « triple win » (food security, adaptation and mitigation) objective requires drawing-up policies that take into account the evolution of agrarian systems. To do so, it is necessary to develop tools to analyse the agricultural production trends from plot to regional scale.

In developing countries, monitoring tools are facing the issue of heterogeneous and sparse information available: limited information networks, small average area of cultivated plots, fragmented plot organisation and diverse management modes. Moreover, the agrarian dynamics are the result of many processes occurring at different scales, which raises the issue of documenting the main trends without distorting the information when trying to upscale or downscale it.

We propose a methodology to estimate the spatial variability and the time dynamics of agrarian systems at scales appropriate for seasonal risk monitoring and land policy planning.

To do so, we use a mixed scaling approach based on the modelling of spatial dynamics which combines various information sources coming from ground networks, expert knowledge, thematic maps, crop models and remote sensing images.

The novelty of the proposed approach is to use a spatial dynamics modelling language, Ocelet, based on interaction graphs: the graphs allow us to link information at different scales, and to integrate the spatial constraints and variability, central to the understanding of agrarian dynamics.

The 1500 km² studied area is located in the cotton region of West Burkina Faso. This region displays high spatial climatic variability and has undergone notable transformations these last two decades due to high population growth and cultivated area reaching its saturation point. The main result presented is the simulation of the expansion of cultivated areas at the expense of forests, and also the evolution of cropping systems, taking account farmers strategies, climatic variability and spatial heterogeneities.

36. Climate Smart Agriculture, mitigation and adaptation, agro biodiversity conservation in Georgia

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Climate change is a global phenomenon involving changes in natural and social systems at all scales in Rural Areas. It is a problem characterized by uncertainty about present and future of Agriculture in Georgia where climate change is already affecting agriculture and negative impacts are evident. The implementation of solutions for the ongoing climate change process in Georgia and in the whole South Caucasus will profoundly challenge some of our most powerful and persistent instruments like the adoption of Climate Smart Agriculture. We, researchers of the Association for Farmers Rights Defense (AFRD), are actively engaged in the evaluation and risks assessment processes as the challenges that climate change presents are increasing. Climate patterns play a fundamental role in shaping agro and natural ecosystems on which human economies and cultures of Georgia are based. These patterns are being negatively affected as increasing levels of greenhouse gas (GHG) emissions from the global economy influence natural climatic and oceanic systems. Climate change is a pressing issue – one that has implications in all the other areas where we work. The concern is that the inherent ability of climatic and oceanic systems to function normally is being compromised and will be less efficient in providing essential ecological goods and services that sustain the conditions for life. Our research team on climate change reflects the AFRD's research profile in evaluation of climate change negative impacts and works on implementation of Climate Smart Agriculture adoption by farmers in different regions of Georgia. Exploring the causes, impacts and solutions to climate change involves interdisciplinary research that combines insights from the Science on Plants and Animals Agrobiodiversity Conservation and Soils and Waters Conservation and from mitigation and adaptation reseraches. The quality of our climate change research is demonstrated by our presence for providing extension and advisory services for Farmers on Climate Change and our recommendations are oriented towards the creation of in situ, ex-situ, in-farm, on-farm plants agro biodiversity conservation banks and the collection of germplasm also. Much of our research actively engages key decision makers from the community, Agri-business and Agricultural Cooperatives for the identification of a wide range of processes that have changed our climate in the past; plants biotic and abiotic stress, soils and groundwater's conservation, sanitation and preservation from contamination. Georgia is one of the richest countries through its agrobiodiversity as a result of the natural selection processes and the careful selection and inventive developments of local farmers, herders and fishers over millennia and managing the risks associated with climate variability is integral to a comprehensive strategy for adapting agriculture and food systems to a changing climate when agrobiodiversity is threatened by the negative impacts. Climate variability today and long-term climate change are two ends of a continuum of time scales at which the climate varies and impacts agriculture. The damage of climate shocks, such as droughts or floods, to health, productive assets and infrastructures can impact livelihoods long after the shock has passed especially on agrobiodiversity.

37. Sensor-aided conservation agriculture: climate smart nitrogen and weed management in maize-wheat system

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Several cConservation aAgriculture (CA) on-farm studies have projected weed proliferation and nitrogen immobilization as major trade-offs despite resource efficiency, enhanced ecosystems services and productivity. Sensor-aided (precision) CA towards sustainable intensification is based on complementary systems: soil-plant based management to read the nitrogen status of plants in conjunction with brown manuring and herbicides to suppress weed. An ongoing experiment that is being conducted at the Indian Agricultural Research Institute Research Farm, New Delhi from 2013 to 2015, evaluates four nitrogen (N) levels as aided by sensor-based GreenSeeker™ (GS), 50% N basal + 25% N broadcast 30 DAS + 25% N GS-guided; 50% N basal + 50% N GS-guided; 80% N basal + 20% N GS-guided and business-as-usual farmers application, 100% N basal and three weed management (brown manuring with *Sesbania aculeata*, herbicides-mixtures and weedy-check) treatments in maize-wheat system. We investigated (i) whether the GS efficiently optimizes N economy, and (ii) the interactive effects of nitrogen and weed management on productivity, soil properties and greenhouse gases (GHGs) emissions (N_2o and CO_2) and weed population. Preliminary results showed that the GS-guided N (50% N basal + 25% N broadcast 30 DAS + 25% GS-guided N) and brown manuring resulted in an efficient N and herbicide use economy with an increase in crops yield to the tune of 17-45% at various weed management options when compared with farmers' practice. Brown manuring significantly suppressed weed dry matter yield and population was 27-45% lower as recorded in the GS-guided treatments. Enhanced soil quality as a function of reduced dry bulk density and increase carbon accumulation was recorded as opposed to the initial soil condition. Precision CA showed a great prospect of a "greener" solution that can mitigate the negative effects of over-fertilization and herbicide use (environmentally damaging GHGs emissions) with greater productivity, improved soil quality and suppressed weed invasion.

38. Climate Change from the lens of a smallholders and their landscapes

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Smallholders' farmers and their organizations in their landscapes, have a role in the global debate on climate change. It is an urgency to integrate them, explaining how their practices contribute to mitigate Green House Gases (GHG) while at the same time can adapt to a changing climate. What is their contribution? How can we differentiate and measure it? What type of alliances can revitalize and strengthen the productivity of agriculture from the lens of ecosystem services?
Within a landscape perspective, cases from Indonesia, Kenya, Peru and Nicaragua provide sufficient criteria to analyse the role of smallholders in adaptation and mitigation to climate change, even when this particular role is not fully recognized by the markets. In Kenya and Indonesia, the application of bioslurry in farming is not only generating clean energy though biodigesters, but is also increasing the productivity per yield; the application of Cool Farm Tool also supports the assessment in terms of GHG reductions. In Peru, restoring degraded landscapes can be feasible by a complementary innovation of financial schemes; Cool Farm Tool is also used to provide data in terms of GHG reduction. In Nicaragua, agroforestry systems are in place in coffee landscapes to promote market diversification and food security, stimulating gender equity; an inspired methodology (CamBio2) provides data in terms of energy flows, GHG reduction and family farming.
Working through theory of change a new route can be designed that frames the role of smallholders (men and women) in generating environmental services, while boosting dynamic local economies.
A dialogue between multiple actors could facilitate the integration of new alliances between private sector, research centres and development practitioners, with a clear aim to influence this global debate.

39. Assessing the vulnerability of sorghum to changing climate conditions in West Africa semi-arid tropics

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Rainfed agriculture would remain the dominant source of staple food production and the livelihood foundation of the majority of the rural populace in semi-arid West Africa. Prolonged dry spells during the growing season often lead to significant crop yield losses, a situation that is expected to be exacerbated by climate change. In this study, impacts of climate change on the sorghum production system in West Africa semi-arid tropics was analysed using the most accessible process-based crop models (DSSAT, APSIM and Samara) and simulated at six stations under rainfed conditions. The mid-century future climate predictions by 2069 indicate the productivity of grain sorghum would be diversely affected due to the differences in the GCMs projections in terms of temperature and rainfall. On the average, climate change is projected to reduce low photoperiod sensitivity genotype (CSM63E) grain yield to the tune of 13%, and by 7% for both medium photoperiod sensitivity genotype (CSM335) and high photoperiod genotype (IS15401) across the selected sites. Results also indicate that adaptation strategies like longer grain filling period and sowing date reduced the vulnerability on both the medium and high photoperiod sensitivity genotypes (CSM335 and IS15401) compared to low photoperiod sensitivity genotype (CSM63E). As obtained from the study, proper genotypic calibrations and evaluations of crop models could be used to explain the expected outcomes of future climate conditions on the diverse photoperiod sensitivity sorghum genotypes available across semi-arid area. Also, these results would serve as reliable tools towards the understanding of future climate change and adaptation options to be implemented, which could be shared among farmers and development partners interested in food security issues in West Africa semi-arid zone.

40. Network of experiments to phenotype contrasted sorghum and to model its adaptability in West African environments

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Characterizing the environment, understanding farmers' requirements and evaluating crop responses to the environment is essential to choose which crop or even which variety is better adapted to the farming systems. Crop models can help to direct this choice. However, use of models requires excellent datasets to facilitate their calibration and validation. In West Africa, sorghum is traditionally the lead cereal and staple crop. A high diversity of sorghum varieties is farmed, but detailed data on these varieties in this specific environment is scarce. We aim at addressing this issue by setting up a network of experimentations in West Africa to characterize contrasted sorghum varieties and to assess their adaptability to different agroecological zones of West Africa. These varieties differ with respect to architecture (tall or small), uses (grain, biomass or dual purpose), composition (cellulose, lignin), and phenology adapted to different targeted regions in West Africa. To represent the diversity of the environment, three main sites in three major countries of the region have been chosen to test these ten varieties according to a rainfall gradient: (1) 700mm in Senegal, (2) 950mm in Mali and (3) 1150mm in Burkina Faso. The main crop traits characterized are phenology, number of leaves, plant height, leaf area index, organs biomass and grain yield, all essential data for good model calibration. The first results are (1) a comprehensible database of ten contrasted West African sorghum varieties, all tested in three major sites in West Africa, and (2) calibrated crop models (DSSAT, APSIM and SAMARA). These models will then be used to direct our choice of adapted cultivars to the right environment. Also, calibration of multiple models will enable to assess the uncertainty in the decision we take.

41. e-Agro Climate Initiatives - Ghana

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INTRODUCTION

Climate Change and its adverse impacts have been felt across many regions of Ghana and also in the majority of developing countries. This project has been under implementation since 2012 particularly as a solution to the visible effects and impacts of erratic climatic patterns affecting crop and animal production in catchment communities while encouraging environmentally friendly practices by farmers. This project also seeks to promote innovative ICT Climate driven practices and policies which have successfully increased agricultural productivity and profits in catchment communities and have proved to be very resilient to climate change on agriculture for the targeted farming communities thereby improving food security in the project's catchment towns in Ghana.

DESCRIPTION

Setting up virtual online farmer association meetings: these were aimed at enabling farmers from different farming towns and communities to communicate and share challenges and the problems they have been facing in their villages, access to financing, to new agricultural practices and to new innovative systems and practices including market information and latest prices for agriculture production and farm crops. Remote collaboration and applications of ICT's for virtual interactions will significantly reduce greenhouse gas emissions caused by travel. 0.5 billion tonnes CO_2e can be saved without any major investments.

Agriculture e-commerce: We have successfully assisted farmers, amongst which our project field teams assisted farmers, in selling their farm productions through selected Messaging Applications on their mobile devices that allowed them to be in touch with potentially interested buyers without the need for the farmers to travel long distances to sell their products in nearby marketing centers. By this online transaction fuel usage and emission by vehicles, as well as time and money, have been saved for the farmers using this service. Depending on uptake, these solutions can avoid emission of more than a billion tonnes of CO_2e.

42. Climate-smart, site-specific agriculture: reducing uncertainty on when, where and how to grow rice in Colombia

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In many parts of the world, farmers have been using traditional calendar landmarks to make climate-related decisions such as what, where and when to grow a crop. Such approach is being challenged by the increasing climate variability that makes climate less predictable. In the last five years, national average rice yields have dropped in Colombia (from 6t/ha in irrigated rice before 2009 to 5t/ha today) and rice growers have not managed to recover since then.
New approaches are required to provide growers associations and farmers with updated and relevant information that can support the decision-making process and make them more resilient to climate variability. Novel use of ICTs and the possibility to follow the principles of Big-Data for capturing, analysing and sharing large amounts of information in agriculture offer an alternative to approaches based on small scale studies.
We used empirical modelling techniques, especially machine learning, to analyse commercial harvest monitoring data from the Colombian National Rice Growers Association (FEDEARROZ), combined with climate information at daily resolution. We identified main climatic limiting factors in several rice producing areas. We then connected our results to seasonal forecasts to generate recommendations for rice growers in two regions.
The methodology proved its capacity to generate relevant knowledge out of commercial data (noisy but numerous). FEDEARROZ is currently testing and sharing the results with their farmers. Rice breeders have also shown interest in these results as they can get information on the response of rice varieties to climate under commercial conditions, which could guide their efforts to release more resilient germplasm.
This study is the first step towards a complete decision-support system for farmers in Latin America that will also include soil and crop management factors. We developed a two-ways information system to support the data capture, based on a web platform, android app and a cloud-hosted SQL database.

43. Microclimate drives pests in complex agricultural landscapes: how to monitor and analyse fine-scale climate data?

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In the context of global warming and increasing climatic variability, a major uncertainty that hampers effective pest management is that related to the thermal characteristics of agricultural landscapes that can potentially have profound effects on insect pest dynamics. A better assessment of the spatiotemporal thermal regimes in agrosystems is therefore a key step towards understanding their responses and potential resilience in the face of climate change. Here, we present a methodological framework to quantify the fine-scale spatiotemporal thermal heterogeneity in complex agricultural landscapes and show how microclimates influence crop pest ecology. Our study was carried out in the Ecuadorian Andes where the climatic conditions allowed the main crops to be planted and harvested all year round, thereby creating an agricultural landscape mosaic of a wide variety of crops at different phenological stages. To quantify the thermal heterogeneity associated with such a mosaic, we recorded temperatures in the three environments experienced by most crop pests over their life cycle (air, plant and soil) for all possible combinations of altitude, crop and phenological stages. We also performed Unmanned Aerial Vehicle thermal imagery flights to capture the fine-scale spatial variability of temperature within these agricultural canopies. We used Fourier transform to compare those microclimate data with coarse-scale climate data and we highlighted the consequences of their use in a performance model for several pests. We found that crop vegetation structure was an important determinant of fine resolution microclimate and a major modifier of temperature extremes experienced by pests. We pointed out that microclimate *vs*. coarse-scale climate inputs in performance model delivered significantly different results. Our study stresses the need to capture temperature variations that occur at resolution relevant for organism to understand pest distribution and develop detailed adaptation strategies for pest crops management under climate change.

44. Enhancing women farmers' access to climate smart technologies through participatory approach in rice farming households

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Climate change is often seen as a technical problem, requiring technical solutions. Yet, there are many social (including gender) dimensions to this complex issue which remain unaddressed. Studies show that poor, vulnerable and marginalized groups – particularly the women – have the least capacity or opportunity to CSA which can prepare them for the impacts of changing climate. Moreover, examples of social and gender inclusive participatory approaches in the development, evaluation and scaling out of CSA are very few. To fill in this gap, this research was conducted to: a) understand the linkage between climate change and gender in rice-based farming systems; b) identify the gender gaps in access to assets, technical knowledge, information and resources; and c) use participatory varietal selection (PVS) approach to reduce these gaps. This study was conducted in 2013 in Hau Giang and Bac Lieu provinces which represent submergence/flood prone and salinity prone rice agroecologies, respectively in South Vietnam. Qualitative and quantitative methods were used in collecting gender-disaggregated information. PVS with the gender perspective was conducted under the project "Climate Change Affecting Land Use in the Mekong Delta: Adaptation of Rice-based Cropping Systems (CLUES)" coordinated by the International Rice Research Institute (IRRI) in collaboration with Cuu Long Delta Rice Research Institute (CLRRI) and Cantho University in Cantho, Vietnam. Findings reveal that women's perspectives matter and should be incorporated in PVS (researcher-managed trials, farmer-managed trials and sensory evaluation) protocols. Through CCAFS in Southeast Asia, CLRRI distributed stress tolerant seeds to 100 female members of Village Women's Association covering 13 hectares and trained women farmers on rice production technologies. Results show that this pilot project led to women's empowerment, and has the potential for reducing gender disparities in access to opportunities, increasing productivity, reducing poverty, ensuring food security, and building climate- resilience of millions of Vietnamese farming households.

45. Assessment of community based biodiversity management for adaptation to climate change in Kaski district, Nepal

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A survey was conducted in the various locations of the Lekhnath municipality 9, 10 and 11, May-June, 2013, in 80 households to assess climate change and its implication on the agricultural production and ultimately developing the community based agrobiodiversity management as one of the best technique to cope with climate change. Majority of the farmers have perceived that extremities of summer and winter increased, occurrence and amount of the rainfall was decreased whereas the occurrence of the intense and irregular rainfall was increased. Similarly, the onset of the monsoon was also later and the period of the dry spells was increased. The trend analysis of the 30 years data (1982-2011) of the temperature revealed that the maximum temperature was increasing by 0.0317 per year as well as minimum temperature by 0.0571 and the rainfall data of the site showed that average rainfall was increasing by 11.908 per year. An analysis on the major climatic hazards showed that the hazards were heavy rainfall, hailstone, drought, landslides, flood, wind and insect pests. Community based Biodiversity Management (CBM) technique was found to be the most effective approach to cope with the undesirable impacts of the climate change. The CBM initiatives developed by community were local varieties conservation, biodiversity block areas, saving and micro credit groups, participatory plant breeding, value addition and quality enhancement, home garden, biodiversity fair and biodiversity exhibition. Hence, it can be concluded that CBM practices played a significant role in coping with the climate change directly or indirectly.

46. Degradation of forest and agricultural resources and adaptation strategies in Middle Casamance (Senegal)

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The impacts of climate change, which appear across the globe, are felt particularly in sensitive ecosystems (wooded savannahs, forests) as those in the Middle Casamance in Senegal, which are particularized by the diversity and richness of its resources, based on the survival of the largely rural population. The quality and quantity of available resources are important determinants of their ability to support and sustain the needs of the population.

However, degradation, much maligned, is not quantified and spatially assessed especially in Middle Casamance. Processing satellite images of Landsat from 1970 to 2008 achieved the land use maps showing the spatial and temporal dynamics of resources and quantifying spatialisation of retained land uses classes. The collection of field data led to a better understanding of the factors, the consequences of the degradation of agricultural and forest resources but also the strategies developed by the people.

The results clearly show that forest and agricultural resources in Middle Casamance are recorded in a regressive dynamics; sectors such as agriculture experience lower surfaces. This deterioration is causing land re-organizations and socio-professional retraining of the actors.

In this paper, we will discuss the results of the spatial assessment and quantification of degradation of forest and agricultural resources and ongoing adaptation strategies to address climate change in Middle Casamance.

47. Climate change and adaptation strategies of households as threats to food security in rural Southwest Nigeria

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Climate change is no doubt one of the emerging challenges that Nigeria and many of the countries in sub-Saharan Africa are facing. In fact, the situation is particularly worrisome especially in countries relying on agriculture as their main source of livelihood. In Nigeria for instance, the agricultural sector provides employment for more than two-third (approximately 67%) of the population and climate change is already taking its toll on this all-important sector. Meanwhile, a number of strategies are now being harnessed by households in rural southwest Nigeria as adaptation responses to climate change shocks. This paper relied on data collected through questionnaire administered on a random sample of 250 respondents in rural southwest Nigeria. A descriptive analysis of respondents' socioeconomic characteristics revealed their average age to be 57 years with only about one-third (34.5%) educated up to tertiary level. Occupational distribution of respondents showed farming as the most important and this is closely followed by the civil service employment sector. Adaptation options harnessed to cushion the effect of climate change shocks include 'okada' riding (43.9%), attending political rallies (14.2%), taking up menial jobs (9.3%), trading (18.3%) and relocation to neighbouring villages or towns. However, these adaptation options were found to be taking its toll on the food security status of households in the region because some able-bodied men and women have left farming for other income-earning activities. Also, the result of Tobit model employed to ascertain determinants of adaptation options harnessed revealed age, gender, years of schooling, household size, income, season of the year and membership of cooperatives (a form of social capital) as important. Suggested policy prescriptions include investment in capacity building of respondents through education to enhance their earning potential and effort should be geared at encouraging cooperative activities since this can help in risk sharing and mitigating covariate risk like climate change.

48. Analysis of the adaptive capacity of rural farm households to climate change risks In Nigeria

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Rural farmers constitute a large significant proportion of Nigeria farmers' and contributing about 73.5% of total staple food in the country. Therefore, ascertaining their households' risks to climate change becomes imperative. The exposure of these rural farm households' to climate change risks constitutes a big threat to food security in Nigeria. In view of the above, this study analysis the adaptive capacity of rural farm households' to climate change risks in the North Central Region of Nigeria. A multi-stage sampling technique was used to select 300 rural farm households in the study area. The analysis was premised on carefully selected Risks Indices Indicators (RII) and adaptive capacity. These indicators were weighted using Principal Component Analysis (PCA). Risks in this study are taken to be a function of exposure, sensitivity, and adaptive capacity. Also, this study considered historical changes in climate variables and occurrence of extreme climatic events as indicators of exposure. Again, the effects of climate related disasters such as floods or prolong droughts on the livelihood of the rural farm households were considered as the sensitivity indicator. While adaptive capacity of a rural farm household is taken to be possession of the five types of livelihood assets. The result revealed through the absolute value of the weights, that temperature (0.91) and rainfall (0.88) trends contribute much more to the exposure index compared to humidity (0.82) and past experience of floods or prolong droughts in the last five years (0.71). The study further revealed that human assets such as qualification and training (0.87) received higher weights, while dependency ratio (-0.92) decreases the adaptive capacity. It is recommended that government at all levels should endeavour to formulate policies that will improve the adaptive capacity of the rural farm households to climate change risks in the study area.

L3.2 Climate-smart cropping systems

49. Climate smart village model for climate change adaptation and mitigation: implications for smallholder farmers in Ghana

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Smallholder farmers in developing countries who depend solely on rain-fed agriculture are at considerable risk from climate change because of predicted rising temperatures, declining rainfall, and an increase in extreme weather events. They are also among the most disadvantaged and vulnerable groups because of their limited adaptive capacity. In order to ensure food security, promote adaptation and build resilience to climatic stresses, some "climate smart agriculture" (CSA) options are being tested in two communities in the Upper West region of Ghana based on the climate smart village (CSV) model. With this model we try to adapt cropping practices and approaches that are related to local farmers' knowledge, requirements and priorities. Key technologies and practices introduced to farmers in the two communities include improved weather forecasting capacity, climate services, climate-resilient germplasm (drought and Striga tolerant maize varieties and improved cowpea and soybean varieties) as well as sustainable soil and water-management practices. Other practices include use of legumes in crop rotation, reduced/no-tillage, agroforestry, bunds/zai and integration soil fertility management practices. This paper assesses how the CSV model is being used to reduce the impact of climate change on smallholder agricultural productivity in Ghana. The study used data from two CCAFS Project communities in the Upper West region of Ghana between 2012 and 2014. The results so far indicate that farmers in the two communities have developed interest in the project which is highly participatory – with farmers involved in all activities – and intensely practical, in terms of improving crop productivity and incomes. Many of the CSA activities being tested are feasible and affordable. Significant grain yields have been recorded in both communities. Addition of minimal N fertilizer significantly increased the yield of drought-tolerant maize by 133-425%. Maize following cowpea with mineral fertilizer increased grain yields by 45% when compared with continuous maize. Bunding complemented with fertilizer increased maize yield more than threefold. Use of zai with manure increased maize yields by 62%. No-tillage with fertilizer increased maize yields by 65% when compared with conventional tillage. Even without fertilizer addition, no-tillage maize was 76% higher. Farmers have been trained on identifying and evaluating climate risk management strategies and tailoring climate information to their needs. This training was used to build common ground between scientific forecasting and traditional knowledge. Farmers now understand and use seasonal forecasts to improve crop strategies. CSA needs to be strongly supported through national and local policies.

50. Agro Climate Calendar, a simple methodology to identify local adaptation for farm objectives

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Climate change effects such as extreme weather events and pest and diseases can have a high impact on arable farming systems. As farming systems are driven by the objectives from farmers, local adaption needs to support those objectives for adequate adaptation. Simple threshold-based systems that use climate change scenario data in combination with relatively simple agronomic knowledge of the farming system can be used for adaptation planning. The Agro Climate Calendar (ACC) is an example of such a method that has been applied in The Netherlands in an arable farming region with a rotation of potato, onion, carrot and wheat. Simple meteorological thresholds that reflect the impact of climate change events on crop production or product quality are used to calculate frequency changes of events. The frequency changes of events can be calculated on a monthly basis to give farmers information on future risk for specific periods in the growing season. Feedback from stakeholders is used to refine the information with practical information that relates to the farm objectives. Furthermore, the stakeholder-based approach can be used to generate specific data on costs and on the effectiveness of the adaptation measure. For example, the objective could be minimizing risk for food security and in another situation it could be that the objective is to focus on minimizing risk of quality loss of the food produced. With this method data can be generated to do a cost-benefit or cost-effectiveness analysis to compare viable adaptation options for local adaptation. Mitigation potentials for adaptation option can be compared optionally. The ACC method can be applied in any location that has reliable climate change data available on the local scale. An important benefit of the ACC is that it can complement climate change studies that use crop simulation data with information on impacts of extreme weather events and pests and diseases.

51. Drip system and climate change adaptation

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Mauritania is a Saharan-Sahelian country where water is scarce. Since the 70s, climatic conditions are strongly degraded with lower rainfall averages and irregular rainfall.
The locality of Nimjatt (West Mauritania) is one of the poorest in the country. The ACSA[1] project aims at building smart adaptation solutions for the vulnerable community of Nimjatt whose life conditions are worsened by the consequences of climate change. The project will allow fighting land degradation, biodiversity loss and decline of agriculture productivity, through the introduction of a new and more productive cropping system that is less dependent on rainfall.
ATED[2] in collaboration with APEM[3] , two top Mauritanians NGOs, are helping the women cooperative of Nimjatt to implement this community development project based on an agriculture system of 'two-stages' combining gardening (production of vegetables) and fruit growing (fruit production) through little water irrigation techniques, the drip system which is very suitable for this kind of agriculture.
Fruit plantation in the garden create a microclimate for spreading agricultural activities throughout the year, diversifying and increasing agricultural production to better meet the subsequent food shortages due to lack of rainfall and improve the financial situation of households by selling the surplus of vegetables and fruits. This proposed system of agriculture is well suited to women because it demands less physical efforts, it allows quick returns on investment and saves time for other activities and to free school-age children to go to school.
Two surveys show that the community is now in better health since they eat sufficient vegetables and fruits, they have increased their revenue to face other needs than food and their children attend the local primary school more assiduously. The resilience of the Nimjatt community is now better. This project provides adapted solutions to climate change and can be duplicated in other villages suffering from rainfall deficit phenomenon linked to climate change.

[1] ACSA : Adaptation au changement climatique et Sécurité Alimentaire: Adaptation to Climate Change and Food Security

[2] ATED : Association Transparence et Développement: Transparency and Development Association

[3] APEM : Association pour la Protection de l'Environnement en MAuritanie: Association for Environmental Protection in Mauritania

52. Comparison of methodological approaches for durum wheat in-field monitoring and early-yield prediction

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The search for cost rationalization, together with growing environmental consciousness, is guiding scientific research towards the development of 'intelligent' agricultural machinery capable of rapidly performing site-specific management of crops. This turning point must take into account knowledge of in-field crop variability.
The aim of this study is to compare the potential of different approaches for monitoring durum wheat (*Triticum durum L.*) growth and development, particularly addressing grain yield and protein content forecasting ability at the field scale.
In particular, different approaches based on meteorological data, moderate-high resolution remote sensing information, crop modelling and their combination for the development of specific forecasting indices were investigated and compared in the experimental area of Val d'Orcia (Central Italy).
In short, the results suggested that the integration of the remotely sensed fPAR with the crop model CERES-Wheat was able to overcome the problems related to the adoption of the single approaches separately due on one hand, to the lack of detailed input data for the model initialization, and on the other to the shift of the remote sensed vegetation index values among the seasons not due to a real change in the crop productive potentiality. The strength of this approach is that it requires very little input, making it suitable for operational in-field applications.

53. Increasing vegetable research investments in South Africa for climate-smart vegetable research

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The purpose of this study was to estimate the economic rate of return to vegetable research in order to provide motivation and justification for furthering public vegetable research investments in South Africa. The motivation was that public investment in agricultural research including vegetable research has been decreasing over the years in the country due to scarce public funds. The decrease in public vegetable research investments is a concern because vegetable research plays an important role in developing climate-smart vegetable crops that are disease and pest resistant, drought tolerant and of better quality and yield. In addition, vegetable research results in sustainable and innovative vegetable production methods. The study used time-series data obtained from the national statistics of the Department of Agriculture, Forestry and Fisheries, as well as research investment data from the public Vegetable and Ornamental Plant Research Institute of the country. A production function method with a second order polynomial distribution lag was employed to model the effects of vegetable research on vegetable production. The study found that the benefits of vegetable research on vegetable production are spread over a period of 15 years, with maximum benefits derived in year seven and eight after the research investment was made. The economic rate of return to public vegetable research was estimated at 39%. This implies that for every R100 increase in vegetable research, the vegetable industry gains marginal returns of R39. This rate of return is significant and warrants increasing vegetable research investments which would allow research into a broader spectrum of vegetable crops including indigenous and traditional vegetables. Indigenous crops have been found to play an important role in food security particularly in rural communities and have also proved to be resilient, even amidst changing climate conditions. Research would also result in climate-smart production methods of these vegetable crops.

54. Improving farmers' innovation capacity for climate-smart forest and agricultural practices in Bangladesh

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Bangladesh is a small and populated country in South-Asia. Seventy-seven percent of its population lives in rural areas, majority are dependent on natural resources for livelihood (BBS, 2011). Due to ever-growing population, forest land has been decreasing at 2% annually. This is one of the significant factors responsible for climatic change events like recurrent natural calamities and degradation of natural resources. The study was conducted in the Madhupur forest area, which has greatly been exhausted due to conversion of forest into human settlement and agricultural production. Tribal 'Garo' people lives inside this forest, meeting up their livelihoods from forest resources. This is now under threat of unsustainable and environment-antagonistic agricultural practices. Thus, a pilot project was undertaken in the area by BAU to minimize carbon emission through introduction of low emission agricultural practices (vermi-compost and botanical pesticide) in crop production and to increase women's participation in social forestry programs. Video mediated extension approach was used to teach forest community people about the consequences of climate change on their livelihoods. Participatory learning videos were prepared showing the people of the forest community how they may prepare vermi-compost and botanical pesticides and use those low emission inputs in multiple crop cultivation in the deforested land. Findings showed that project beneficiaries are now impressively aware on consequences of climate change. Around 75% of them are now using own-made vermi-compost and botanical pesticide in agricultural production, while 42% of them are using improved cooker which has significantly reduced amount of fire wood for cooking while reducing people's dependency on forest for fire wood and minimizing rate of deforestation. So, it can be concluded that through improving farmers' innovation capacity it is possible to reduce consequences of climate change. However, to make it happen, integrated initiatives are needed from concerned agencies.

55. Finding niches for neglected crops in the semi-arid to better manage climate risk under smallholder farm conditions

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There are many challenges to food production in the semi-arid tropics with high inherent seasonal climate variability and change, low technological innovation, small farm size, high population and poor infrastructure, to name a few. While the use of agro-biodiversity is an attractive strategy for coping with climatic variability, evidence from the field suggests that farmers in semi-arid regions are in fact farming with less diversity. In response to changing demands for diverse agricultural products and accompanying nutrition thereof, identifying niches for neglected crop types with promising market opportunities and system benefits represent a wider window of opportunity for smallholder farmers. Based on extensive field based research in Eastern Africa and India, this paper presents research efforts to: (i) identify neglected crop spp. and compare their productivity under drought/nutrient driven stresses, compared to the more common staple food crops; (2) find niches for lower risk and short season crop varieties and how these varieties may be incorporated into the farming system; and (3) apply crop modelling and whole farm analysis to understanding the interactions of crop type, soil and season in designing lower risk farming systems.

56. Reducing the use of nitrogen fertilizers: how and what potential impact on N2O emissions from French agriculture?

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In order to reduce the greenhouse gases emissions from French agriculture and particularly those of N_2O, we studied the attenuation that could be allowed by a decrease in the use of mineral nitrogen fertilization on annual crops, in France. We estimated the total attenuation at the 2030 horizon and the cost of these actions for the farmer, expressed per ton of CO_2e avoided. The technical actions studied concerned a better and larger implementation of the N balance to calculate N fertilizer rate, improving fertilizer efficiency through adapted practices (timing, N placement, nitrification inhibitors), and increasing surfaces grown with legumes in arable crop rotations and grasslands. Our calculations indicate a reduction in the range 15-30 kg N / year / ha affected by each measure. The mitigation potential would be important in 2030 (without modifying production levels) because of the large areas concerned – especially for improving and extending rational N fertilization and its management. Most of the proposed measures would have negative or slightly positive costs, because they represent a saving of inputs. Implementation still requires additional technical references and consistent changes in the French socio-technical system from all stakeholders.

57. Climate Smart agriculture: farmers' perception and practices in Nepal

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Agriculture is one of the most sensitive sectors of human activities to climate change. It has been accepted that the worst hit by the changing climate are going to be the agricultural community mostly inhabiting in underdeveloped countries. Being an agrarian country along with specific geographic position, mountain topography and weak socio-economic conditions, Nepal is highly vulnerable to the impacts of climate change. Keeping this important issue in consideration, an extensive literature review and field studies in various farming systems in different parts of the country were conducted to comprehend the perception of the farmers about climate change and their efforts to make their agriculture climate smart. Review showed that climate in Nepal is changing significantly and the trend is predicted to continue in the future. This has adversely affected the agricultural production jeopardizing the agrarian livelihood. Field study conducted in various communities in central and western Nepal including both hill and plain areas showed that the farmers were obviously recognizing the changes in climatic variables, especially unpredictability in the amount and duration of rainfall, and temperature extremes. Yields of major crops and are either declining or stagnant. Disappearance of traditional useful plants and emergence of new insect pests, diseases as well as invasive weeds were on the rise. Study also showed that farmers are trying to make their agriculture climate smart adopting various practices such as changing cropping system and calendar; use of early maturing crop/varieties; adoption of conservation practices; emphasis on vegetable cultivation and/or organic agriculture, etc. depending upon the situation. Communities residing close to the forest were found to have the knowledge that forest is necessary in making agriculture resilient to climate change and saving the forest is a must for climate smart agriculture. The paper gives a glimpse of the effect of climate change in Nepalese agriculture along with the practices the farmers have adopted to make their agriculture climate smart.

58. The FACCE-ERA-NET+ project Climate–CAFÉ: climate change adaptability of cropping and farming systems for Europe

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** Coordinators of the project Climate-CAFÉ (started mid-November 2014; 3-year project)*

Climate-CAFE aims to improve the "adaptive capacity" of arable and forage based farming systems to climate change (CC) through ecologically intensive adaptation strategies. Strategies will be evaluated at cropping and farming systems as well as regional levels for "Adaptation Pilots" along a North-South climate gradient in the EU. Three categories of strategies will be evaluated: i) Resistance strategies that seek to maintain the status quo through management actions that reduce perturbations due to CC; ii) Resilience strategies requiring systemic adaptation at field and farm level for increasing the adaptive capacity after a climate disturbance; iii) Transformative strategies addressing needs and possibilities for re-configuration of cropping and farming systems. Strategy evaluation will reveal synergies and trade-offs among objectives and their indicators at different scales under 2050-2100 IPCC scenarios. The proposed adaptation strategies will include improved soil and water management via ecological intensification, including new cultivars and cultivar mixtures, novel rotations, alternative tillage options, and the inclusion of legumes cover- and intercrops. Since adaptation is context-specific, the project will work in "Adaptation Pilots" and local networks of researchers, advisors and farmers, representative of regional cropping and farming systems. Experimental data (SE, FI, UK, CH, FR and SP), expert technical and farmer knowledge, and simulation models at the scales of crops (STICS, DAYCENT), farms and landscapes (MODAM, FarmDESIGN) will be used to characterise adaptation strategies and foster learning in participatory co-design workshops. The expected result of the Climate-CAFE project is an overview of potential CC adaptation measures at the three considered levels for selected sites across the EU, along with mutual learning experiences for improved understanding and acceptability of CC adaptation strategies among farmers and other stakeholders.

59. Climate smart agriculture: Towards a concerted definition of national priorities in Mali

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Identifier les priorités nationales en matière de pratiques d'agriculture intelligente face au climat fut un engagement du Mali en 2013 lors de la COP 19 à Varsovie. En effet, le climat du Mali est en grande partie de type sahélien caractérisé par une irrégularité de la pluviométrie qui se traduit par des années sèches récurrentes. Pour opérationnaliser l'identification et la priorisation des pratiques d'agriculture intelligente face au climat, l'outil de priorisation de l'agriculture intelligente face au climat développé par le programme CCAFS, le CIAT et la Banque mondiale est en cours d'implémentation au Mali. L'approche comporte deux grandes phase : (1) la préparation, le zonage et le listing des pratiques ; (2) sur la base des critères fixés par les acteurs endogènes, les pratiques sont priorisées pour la productivité, l'adaptation et l'atténuation pour les zone agro écologiques ciblées en fonction du centre d'intérêts d'acteurs spécifiques mobilisés et engagés. Ces acteurs sont des décideurs des collectivités territoriales et des départements techniques du développement rural, des partenaires techniques et financiers ou des projets /programmes. Les premiers résultats importants du processus sont : (1) l'émergence d'une vision commune des acteurs nationaux clés et leurs partenaires autour de trois zones à caractéristiques distincts selon l'indice de vulnérabilité (extrême vulnérabilité , très vulnérable, assez vulnérable) et la mobilisation volontaire de groupe d'acteurs pour l'identification et la priorisation des pratiques d'agricultures intelligente face au climat pour chacune des zones spécifiées ; (2) la fixation des dunes pour permettre les activités agropastorales, l'aménagements des vallées rizicoles avec exhaure solaire, la diffusion régulière d'information agro climatique sont les pratiques prioritaires pour les acteurs de la zone d'extrême vulnérabilité où les précipitations annuelles sont inférieures à 400mm; (3)les associations de cultures sorgho*niébé, la régénération naturelle assistée et l'aménagement des champs cultivés en courbes de niveau sont des pratiques prioritaires pour la zone située entre 400 et 800mm par an ; (4) les aménagements des champs cultivés en courbes de niveau, l'association céréales*légumineuses, l'aménagement des vallées rizicoles sont entre autres les pratiques priorisées pour la zone de plus de 800 mm de pluie par an. Tous les acteurs reconnaissent la nécessité de combiner ces pratiques avec d'autres pratiques complémentaires en fonction du système de production et les conditions socioéconomiques des utilisateurs finaux des pratiques.

Processus conduit par l'AEDD, l'Association malienne d'éveil au développement durable (AMEDD) avec le soutien technique et financier du programme CCAFS et du CIAT.

60. New crops for a new climate: understanding farmers' behavior towards sesame and cowpea crops in Sahel

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This paper investigates the role of on-farm water management technologies, as well as the socio-economic and plot characteristics on farmers' decision-making regarding adoption of new crops – sesame and cowpea – facing the new climate conditions in the Sahel. Using cross-sectional data from the driest region of Burkina Faso, we used several econometric methods to ensure the consistence and assess the robustness of the estimates. We used both bivariate probit and recursive biprobit models to check the jointness and the simultaneity of sesame and cowpea adoption decisions. Potential endogeneity arising from on-farm water management technologies is addressed using simultaneous equations approach. The estimates provide several insights. First, there is no evidence for jointness and simultaneous causality in the adoption decisions of sesame and cowpea. Second, there is evidence of endogeneity of both two on-farm water management technologies included in the models including mulching and zai. Third, adoption of on-farm water management technologies plays important roles in farmer decision-making regarding adoption of new crops in the context of a changing climate in Sahel. Also, agro-pastoralists are more likely to adopt cowpea than crop farmers. Fourth, attending a capacity building training on climate change and adaptation and/or soil and water management has a significant positive sign on farmers' likelihoods to adopt a new crop. Fifth, farmers whose production objective is more market-oriented are more likely to adopt sesame crop, while those who mainly produce for the household consumption are more oriented toward cowpea crop. Sixth, credit and fertilizer access has a significant positive effect on new crop adoption. Land ownership is positively and significantly associated with the farmers' likelihoods to adopt new crops as coping strategies to new climate conditions. These various results provide several policy implications to enhance farmers' resilience to climate change and promote a smart agriculture with regards to the new climate conditions in Sahelian areas.

61. Climate change and rainfed agriculture: how to extend the campaign and improve the Burkinabe agricultural production?

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In Burkina Faso, agriculture is the main activity of rural households. It occupies more than two thirds of the workforce and contributes more than a third to gross domestic product. Mainly rainfed, it is a subsistence agriculture which is still little mechanized and therefore highly dependent on climate conditions. In recent decades, climate change has greatly weakened the traditional systems of production through flooding, uncertainty about the dates of the beginning and end of the rainy season and with longer and more recurrent dry spells. Supplemental irrigation consists in bringing water to crops in case of dry spells, by mobilizing water from a dam, a boulis, a well or any other water resource. For areas far away from these water resources, runoff harvesting basins which are built to collect water and irrigate crops in case of dry spells, contribute to the sustainable management of waters and lands. The practice is increasingly accepted in the farmer environment and the government plans to subsidize the construction of over 10,000 basins in 10 of the 13 administrative regions of the country. A literature review combined with producer surveys and experiments, conducted within the framework of a research-development project on supplemental irrigation and climate information, allowed to obtain a number of results. Supplemental irrigation as the only discriminating parameter between two agricultural plots enables improved yields of over 25%. The early start of the campaign may be wedged since the first rains from the second decade of May, by keeping animals in sheds and under the condition of a period not longer than twenty days, between the first rains able to fill the basin and the actual start of the rainy season. According to the agro-climatic zone and the level of sealing of the basin, water can be stored between 30 and 90 days after the last rains, allowing extending the campaign by gardening or relay cropping. By combining supplemental irrigation with techniques relative to water and soils conservation, protection and restoration of soils, the use of organic fertilizer and improved seed varieties, household farms could enhance their adaptation capacities to drought and dry spells.

62. Evolution of the rainy season and peasant adaptation in the Northeast of Benin (West Africa)

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Agriculture occupies a prominent place in the Beninese economy: 70 % of the active population, 39 % of gross domestic product and 90 % of the country's export earnings. The variability of rainfall is one of the main factors of vulnerability of this agriculture mainly rainfed. Particularly in the Northeast of Benin, the agricultural production depends on the quality of the single annual rainy season.
The present research analyses, on the one hand, the evolution of some descriptors (start and end dates, length, frequency sequences of wet and dry sequences) of the rainy season in the Northeast of Benin during the period 1951-2010. The daily rainfalls of six meteorological stations (Malanville, Kandi, Bembereke, Ina, Nikki and Parakou) have been used. The rainy season has been defined according to the approach of Guèye and Sivakumar (1992). The different descriptors of the rainy season have been studied using a frequency analysis, the non-parametric test of Pettitt (1979) and the test of Student. The strategies of adaptation of 160 peasants were collected by an investigation. These strategies have been analysed using a principal component analysis. The results show that, overall, the starting dates of the rainy season are more unstable than those of its end.
For three stations (Nikki, Ina and Bembèrèkè) the length of the rainy season has known breaks (between 1966 and 1984) marked by a reduction of 17 to 22 days of its duration.
Unlike all other stations, Parakou has recorded an increase (+ 43.34 %) of the number of days of rain. Faced with this instability of the cultivation season, the peasants have developed strategies, amongst which the most practiced are the modification of the traditional planting calendars, the adoption of species and varieties more resistant, or the extension of the cultivated area.

63. Fitting sweet potato into low input cropping systems within contrasting agro-ecologies of KwaZulu-Natal, South Africa

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Crop production is subject to suitability of specific agro-ecologies and farmers' choices of crops are often influenced by agroecology more than anything else. Changes in agroecological conditions now challenge the ability of traditional staples to continue delivering food and nutritional security to communities residing in the agro-ecologies which they have been well suited to. In addition, farmers lack the mechanisms to adapt timeously. Identifying crops with wide adaptability and suitability to a range of agroecological zones may assist smallholder farmers to cope with changes in climate and edaphic factors specific to these agro-ecologies. Sweet potato is a versatile crop with wide adaptation to a range of environment and soils. The objective of the study was, therefore, to assess growth, physiological responses and yield of locally bred sweet potato cultivars grown under low-input agricultural system in different agroecological zones of KwaZulu-Natal.

Three sweet potato cultivars (A40, A45 and 199062.1) were used for the experiment, two (A40 and A45) of which were bred at University of KwaZulu-Natal (UKZN) and the third (199062.1) was sourced from the International Potato Centre (CIP). Cultivars A45 and 199062.1 are orange-fleshed and cultivar A40 is white-fleshed. These cultivars were planted at three smallholder plots (Deepdale, Umbumbulu and Richards Bay) located in three different bio-resource groups/ agroecological zones of KwaZulu-Natal, South Africa. At each location, experiments were laid out in a randomised complete block design (RCBD) replicated three times. Experiments were repeated over two seasons in each location. A fertilized trial was only planted adjacent to the experimental plots during the second season for comparison purposes. Plant growth and physiology data collected included vine length, leaf and branch number, stomatal conductance (SC) and chlorophyll content index (CCI). At harvest, whole plant, above ground and below ground biomass, as well as harvest index (HI) and mass of marketable storage roots were recorded. Data were subjected to analysis of variance (ANOVA) using GenStat® version 14. Tukey's test was used to separate means at the 5% level of significance.

Sweet potato planted at Richards Bay (a coastal sandy soil location) recorded low stomatal conductance (SC) and chlorophyll content index (CCI). This consequently resulted in reduced vine length, leaf number and branching of sweet potato plants. Plants in the other two agro-ecologies (Deepdale and Umbumbulu) located further from the coast and in different agroecological zones recorded higher SC, CCI and general plant growth. High evapotranspiration (ET_0), high temperatures and low water retention capacity of sandy soils created drought stress conditions in Richards Bay. This caused disruption of photosynthetic activities and translocation thus reducing harvestable plant parts. The other agro-ecologies (Deepdale and Umbumbulu) were characterized by clayey nutritious soils as compared to Richards Bay, and drought stress was less pronounced than in the other agro-ecologies despite similar ET_0. Biomass and storage root yield followed a similar trend as plant growth and physiology at these locations. Richards Bay recorded very low storage root yield (5.4 and 5.0 t ha^{-1}) in both growing seasons indicating that it is not suitable for these sweet potato varieties. Deepdale storage root yield was very high (42. ha^{-1}) during the first growing season (2012/13) but reduced by 67% (13.6t ha^{-1}) during the second planting season. Yield from Umbumbulu was stable across both seasons, (29.4 and 28 t ha^{-1}, during 2012/13 and 2013/14, respectively). This indicates that the agroecological zone within which Umbumbulu is located is conducive for these varieties. Adding fertilizer only improved storage root yield in Richards Bay, otherwise yield did not increase after adding fertilizer in the other two agro-ecologies. Cultural practices and good natural soil nutrition were responsible for storage root yield increases in Deepdale and Umbumbulu. The orange-fleshed sweet potato A45 showed better environmental plasticity than the other two. Cultivar 199062.1 responded well to fertilizer application and should be cultivated were farmers have access to inputs such as fertilisers. It was concluded that the selected cultivars were suited for low-input agricultural systems. The adaptability to a range of agro-ecologies and low-input

agriculture are desirable traits for climate smart agriculture.

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64. Study of sequestration of soil organic carbon under conservation agriculture and choice of simulation model

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Agriculture is a structuring agent of rural areas, shaping the development of societies and the management of natural resources. It now faces major challenges: necessity to produce more, better and with less land, less water, less fossil energy. With the purpose of protecting resources, farmers have to solve environmental problems while continuing to produce to meet the growing needs of people and markets. This calls for a radical transformation of Moroccan agriculture and initiates a new agricultural development cycle, called the Green Morocco Plan. This plan must ensure the preservation of a sustainable food security and the emergence of ecologically intensive agriculture.

Soil management can play opposing roles to climate change. Depending on the relevant gas, soil types, cultural practices and climate itself, the soil can contribute to or, conversely, slow climate change. It is essential to understand its operation in relation to the carbon cycle and nitrogen in order to best use its regulatory capacity, especially as carbon storage in soils can ultimately integrate carbon accounting. On the other hand, the soil can play a role in adaptation to climate change: good soil management, including organic matter may, to some extent, store more carbon, limit the effects of drought by increasing the water reserve. Given these issues, conservation agriculture (CA) clearly appears as a coherent response. CA covers 117 million of hectares worldwide but is not yet sufficiently known by Moroccan decision-makers to ensure ownership and adoption by the farmers or their associations. Therefore, it is essential to develop a prospective analysis and deep research and finally to propose conservation agriculture in response to rising energy issues, soil depletion and climate change. The purpose of this reflection is to develop knowledge and bring tangible indicators, in support to scientific experts and policy makers and opinion leaders, to help them undertake and facilitate the adoption of these gentle environment handling systems in Morocco. The overall objective of this study is to sustainably reconcile environmental and food security in Morocco through the adoption of the principles of conservation agriculture. This reconciliation is a multifaceted scientific research field where the emergence of generic knowledge is still low. The specific objective is to include conservation agriculture in an innovative scientific approach as integrated and complete as possible able to produce knowledge on ecological and geochemical processes in conservation agriculture-related dynamics and carbon sequestration. The ultimate goal is to adapt and validate a model of biophysical factors and specific conditions of conservation agriculture, and develop decision-support indicators to improve the perception by the actors and direct adaptation to donors of agriculture conservation.

The introduction of conservation agriculture is causing profound changes in the functioning of the nature of agroecological systems to improve the valuation of ecological and geochemical processes. In other words, it can help increasing the physical productivity of cropping systems and profitability, but also provides many ecological services such as soil conservation and biodiversity, carbon sequestration, plant biomass production and control of certain pollutants. Conservation farming systems contribute to increasing the organic matter content of the soil, especially on the surface, and carbon storage in the soil. It was estimated at 0.1 to 0.4 tons of carbon per hectare per year for the surface horizon (0-20 cm). Crop residues on the surface play a major role in this process. The carbon accumulation is however variable as a function of the soil layers, and very sensitive to clay content, which acts on the stabilization of the organic matter.

In annual cropping systems, crop management and crop residue management determine the level of annual returns of organic matter to the soil. Their effect on the evolution of the soil carbon stock is a function of organic matter fluxes as well as their quality, biochemical composition and physical characteristics (particle size, surface location or depth of incorporation into the horizon worked).

This study will focus on the dynamics of organic matter in the soil, especially the consequences of the inputs of plant residues and their location on the stocks and fluxes of carbon and nitrogen, associated microbial activities, transport and fate solutes (soluble carbon, nitrate) under conservation agriculture. The location of plant residues in the soil determines a number of climatic factors, and provides the chemical and biological environment interacting with their physical characteristics ultimately influencing back decomposition. First, the intrinsic properties of the residues (biochemical nature and physical and morphological characteristics) confer a number of properties, such as the proportion of soluble compounds. Second, their location will determine the distribution on or in the ground, and the terms of microbial colonization of the residues. This study will also focus on determining the biochemical characteristics of residues or mulch, their water retention properties and hydrophobicity which will govern the decomposition rate, the dynamics of water and solutes (soluble carbon) underlying the mulch. Different approaches will be combined to assess the most relevant indicators to study these processes: surface area, particle size fractionation, contact angle measurements, chemical composition.

We also conducted a study of the effects of mulch on the future of carbon (mineralization, humification), mineralization - organization of major elements (N, P), and transport (soluble carbon, nitrate, etc.). Effort will subsequently experimentally reveal a small number of status (models) representative of the actual situations (soil columns or reconstituted soil columns intact with residues of mulch) on the preservation of agricultural soils, allowing to observe the jointly breakdown of residues (marked or not), settlement terms and microbial activities and their distribution in the soil, solute transport, and contaminants.

Another major and permanent concern of the study of soil organic carbon is to break the black box (organic matter), that is to say, to divide the whole into subsets of behavior and homogeneous properties, connecting these sub-assemblies together. Due to their many and varied characteristics, we can say that the area of the organic material comprises numerous dimensions. Only the quantification of particulate organic matter (rapid renewal) was performed in research on conservation agriculture in Morocco. However, their use for this purpose requires a regional referencing and stalling.

Soil carbon is a dynamic system varying between inputs by vegetation (crops and weeds) and mineralization by microorganisms. Carbon isotopes tracing is essential to determine the time residences of natural and artificial carbon-14 and natural carbon-13 in conservation agriculture. This is to establish a soil carbon compartmentalization, that is to say, a division into subsets of different biodegradation rates. Factors affecting the amount of carbon incorporated into the soil are essentially the factors of crop production (light, soil moisture, humidity, soil texture and mineralogy, temperature, nutrients and fertilization, fauna and microbes, pH and cation, partial pressure of CO_2). These factors may, if necessary, be tested under lab conditions and also modeled.

The modeling of carbon dynamics is a fundamental tool for the estimation of actual and potential changes in soil carbon stocks. Kinetic models are the base, but beyond that they allow a multivariate description of soil carbon stocks, where time is one of the explanatory variables among others (soil type, climate, production and land use).

In my detailed study of different carbon balance simulating models (RothC, CENTURY, Henin and Dupuis, ICBM, CN -SIM, DNDC), of their advantages and disadvantages, and their compatibility with the characteristics of Moroccan soils under conservation agriculture, I especially chosen DNDC (Denitrification - Decomposition) based on the objectives, variables to be taken into account, the studied system and performance models that can be tested by comparing the results of simulations of different models.

65. Integrated approaches to adaptation to climate change and food security in Maradi (Southern Niger)

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Our research first consisted in demonstrating the link between climate variability/change and food insecurity in the Sahel and in Niger. We then diagnosed the factors governing food insecurity in Niger and specifically in Maradi (Southern Niger) in a context of climate variability and change. We finally tried to better understand the mechanisms developed by local communities in addressing the issue. On this basis, we proposed alternative adaptation options for Maradi district.
Three major causes govern food insecurity in Maradi: climate variability, poverty and bad governance. The governance factor was revealed as a triggering or exaggerating factor of the nine food crisis experienced in Niger between 1967 and 2012. Our investigations show that communities in Maradi have a quite strong resilience to food insecurity and food crises due to the precarious but effective strategies they have been developed particularly around Social Capital. Endogenous technologies developed by these communities to boost their agricultural production are proved to be moderately effective but limited to ensure the production to cover the households' food needs for only few months. Less than 17% of households surveyed said they completely rely, for 9 to 12 months, on their crops to meet their food needs until the next harvest.
Given the above diagnosis, we have proposed new types of agroforestry systems as sustainable alternatives to address food insecurity in Maradi. These farming systems combine technical environmental, economic and social aspects. One of the major feature of these farming systems lies in their ability to sequestrate (instead of emitting) carbon and organic matter while food production is sustained. These "third generation" farming systems help to avoid itinerant agriculture (thanks to continuous soil enrichment with organic matter), consider the environment as an entire production factor, mainstream livestock and enable poverty alleviation.

66. Can woody plants management provide soil amendments to enhance agroecosystem productivity and resilience in West Africa?

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Soil degradation and fertility loss pose severe threats to the livelihood of farmers in sub-Saharan regions. Due to the need for land, continuous cultivation with staple food has gradually replaced previous shifting cultivation systems, so that fallow periods have considerably reduced and no longer fulfill their soil regeneration role. Here we explore the use and management of native woody resources for providing an *in situ* renewable organic amendment as a basis for increasing soil carbon and biological status, thus sustaining fertility, enhancing water capture and utilization and therefore buffering climatic stress. In areas such as the central plateau in Burkina Faso, slash- and drought-tolerant shrub species are commonly present in farmers' fields. Cut branches from these shrubs are sometimes placed on degraded soils as part of traditional soil restoration practices. Moreover, shrubs tend to intercept sediments and leaves and promote biological activity whereby they may form fertility islands of increased crop yield. We will review available data on traditional practices and current co-innovation efforts and outline first results from an EU-supported project we have initiated in Burkina Faso and Senegal (ERA ARD WASSA). This project is investigating if a sustainable use of native woody resources could be made, in combination with other organic sources such as crop residues or manure, to amend soils and help preserving fertility at the whole field scale. Through experimental plot trials and farmers' fields surveys, we are evaluating how woody residues use and management practices may impact agronomic performance and soil biological processes. Crop response to use of ligneous material will be linked with the availability and distribution of woody resource in the landscape, and the ways it could be eventually increased and sustainably managed. The socio-economic implications of implementing such practices are also considered.

67. Dynamic capacity of the adaptability of steppe sheep breeding systems in response to the challenge of climate change

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In order to better adapt to cyclical and persistent drought, sheep herders in the Algerian steppe often adopt proactive strategies involving various resources. They have also learned to combine local expertise and exogenous knowledge (scientific and technical). Our inquiry focuses on the ability of farmers to adapt their practices. The study hypothesis concerns the capacity of farmers to combine their various assets: social, human, natural, physical, productive, financial, etc. To achieve a clear understanding of the practices implemented, we opted for a systematic approach and participatory tools. We observed the practices of three breeding systems (sedentary, semi-transhumant and migratory) and surveyed 86 agro-pastoralists in the El-Guedid Djelfa region. Our main results show that the agro-pastoralists' rationale is one of continuous adaptation. All the livestock systems studied have managed to maintain themselves and reproduce using anticipatory strategies to ensure easy access to various local fodder resources (self-produced, rented and purchased). They combine their capital (resources or assets) in various ways in their decisions, which determine how they will perceive and anticipate drought situations. Human and social assets are important elements in the way in which farmers respond to events that affect their business. Studies are under way to assess the resilience of these systems in the future, hence the question that is the subject of our ongoing work: is farmers' current capacity to adapt sufficient to cope with the scale of the climate change challenge?

68. Do practices of Sahelian smallholder farmers impact native agroforestry shrubs functioning?

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During the last decades in Sahel, rainfall variability combined to land-use changes in order to supply increasing population (3%/year) with food has led to a drop in cereal production. An agroforestry system made of *Guiera senegalesis* shrubs and millet crops is supposed to be sustainable in Niger because millet production increases visibly around shrubs. However, cutting practices could prevent the system from sustainability. Yearly in crop fields, before sowing and during the millet growth, shrubs are cut back and resprout immediately. Until now, the functional impacts on shrubs have yet not been addressed. To do so, we propose to compare leaf water potential and stomatal conductance between shrubs located in old fallow, young fallow, and crop fields. Leaf transpiration rate (E) and soil-to-leaf conductivity (KS-L) were deduced. Furthermore, leaf area, stem area, stem length were measured on shrubs. Soil water content and surface fluxes were monitored with an Eddy Correlation technic at plot scale. Results showed that leaf water potential decreases more in mature shrubs than in resprouts, in response to seasonal drought, suggesting that resprouts are less stressed. This is coherent with more soil water content measured in crop field than in fallow plots. In addition, it was observed that stomatal closure is coupled to leaves fall, which maintains viable water potential in mature shrubs during the dry season, but is decoupled in resprouts. Resprouts grow throughout the dry season thanks to KS-L twice higher than in mature shrubs, supporting thus their intensive regeneration. Consequently, resprouts induce a low but permanent rate of evapotranspiration at plot scale during the dry season. This adaptive strategy is probably common to many woody species that face regular disturbance in periodic drought stress. However, the sustainability of such practices remains to be checked, especially the threshold of the resource exhaustion under repetitive yearly cutting.

69. STICS: a generic and robust soil-crop model for modelling agrosystems response in various climatic conditions

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The engineering of a climate smart agriculture will strategically depend on the quality of process-based agricultural models used to assess candidate solutions of adaptation and mitigation of climate change (CC). STICS is a dynamic soil-crop model which has been developed in France at INRA since 1996 (Brisson *et al.*, 1998, 2002, 2003, 2008). It simulates production and environmental impacts of cropping systems, including one, two intercropped or several successive crop cycles. It simulates both crop production (quantity, quality of annual, perennial, herbaceous and woody plants), and environmental outputs as water drainage, emissions of CO_2, N_2O, NO_3, NH_3 and soil C, N storages. The model performances have been recently evaluated over a large dataset covering 15 crops and a wide range of agropedoclimatic conditions in France (76 sites) representing 1809 various situations (Coucheney *et al.*, 2015). Model results showed a good overall accuracy and trends induced by contrasted environmental conditions and management practices were also well reproduced. The STICS traits (genericity, robustness, operationnality) enable its use for studying the effects of changes in a wide diversity of agro-ecosystems and with future climate scenarios. Currently, the STICS crop model is used into international model intercomparison exercises such as AgMIP (the Agricultural Model Intercomparison and Improvement Project) and in MACSUR (Modelling European Agriculture with Climate Change for Food Security). At national level, the model is integrated in several programs such as ISOP System-Pastures production evaluation for the Agriculture Ministry, PIREN-Seine research program (water catchment services), Veille Agroclimatique (to evaluate crop climatic conditions), CLIMATOR/ORACLE projects (CC impacts in agriculture)… The model can be used alone (java HCI) or integrated in modelling platforms (RECORD). STICS software and documentation are freely available (http://www6.paca.inra.fr/stics_eng).

70. A model assessment of the adaptation of Mediterranean agroforestry systems to climate change

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Theoretical ecology provides several hypotheses that suggest a better productivity and resilience of ecosystems with higher biodiversity. Furthermore, these beneficial effects are thought to increase with higher levels of stress. As a result, increasing plant biodiversity could be a means to make agroecosystems more resilient to climate change, in particular if the plants that are associated are functionally very different. Agroforestry is a typical example of such a diverse system. Its benefits in terms of productivity in the current climate context have already been demonstrated experimentally. But the potential benefits in terms of resilience in the face of climate change are still unproven. To address this question, we used a mechanistic model that simulates crop and tree growth, both above and below-ground, and their interaction through resource capture (light, water and nitrogen) and microclimate modifications, under the influence of climatic variables. We compared simulations of an agroforestry system (wheat under oak trees) against simulation of trees and crops grown separately, under past (1950-1990), present (2000-2050) and future (2050-2090) climate, in order to test whether agroforestry could help adapt agriculture to climate change. The results showed that agroforestry was more productive than trees and crops grown separately in all 3 climate scenarios. Agroforestry slightly reduced the negative impact of climate change on tree productivity and accentuated the beneficial impact on crop yield (although not significantly). More importantly, mature trees buffered inter-annual variability of crop yield. These results show the potential of agroforestry as a tool to help adapt agroecosystems to climate change, as far as the model can be trusted. Furthermore, the detailed analysis of the simulated variables allowed us to pinpoint possible mechanisms for these favourable effects, providing hypotheses that can now be tested experimentally.

71. The effect of organic amendments and water pulses on GHG emissions from rice production systems using δ13C isotope

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Use of organic amendments in lowland irrigated rice production system increases the soil organic carbon pool, improves soil fertility and also contributes to greenhouse gas (GHG) emissions and global warming potential (GWP) from rice production systems. The alternate wetting and drying and mid-season drainage has been demonstrated to significantly reduce GHG emissions from lowland rice production system.
We investigated the relative contribution of added organic amendments and native soil carbon on GHG emissions in flooded rice, and potential of drainage on reducing either of the two fluxes.
Rice plants were grown in a pot experiment with 2*2*3 factorial design. The treatments were: an arable soil with two different carbon levels (Check: 1.3 and 2.5%); two water regimes (mid-season drainage and early drainage); three nutrient treatments (control, maize straw and maize compost). We hypothesized that i) methane emissions would increase according to the amount of labile carbon in the amendments, ii) that early season drainage was as effective as mid-season drainage in reducing emissions from the amended materials and iii) that drainage was ineffective in reducing soil-C derived methane.
The results have important implications for the choice of relevant and realistic mitigation practices (early *vs.* mid-season drainage) as well as short and long term implications of use of organic amendments on GHG emissions from flooded rice production.

72. Nurse plant effect on mycorrhizal soil infectivity and soil fertility restoration in Madagascar upland rice farming

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On one hand, nurse plant designed those plant species which could have positive effects on the development of other plant species by several aspects. This technology could be a special key to mitigate the effect of climate change on farming by valuing natural resources present in each ecosystem. On the other hand, mycorrhizal soil infectivity and soil enzyme activity are the most sensitive parameters to the variation of plant species' structure and of land use. The long-term experimental site is located in the eastern part of Madagascar. The aim of this study was to select nurse plant among all plant species which are naturally associated with upland rice according to some criteria such as symbiotic status, endemicity, distribution, scattering method as well as mycorrhizal soil infectivity and soil enzyme activity related to each selected plant species. We recorded 17 plant species belonging to a functional group of mainly shrub and herbaceous species which are naturally associated with upland rice. There were 5 endemic and 2 naturalized species such as *Aphloia sp*, *Casearia sp*, *Doratoxylon sp*, *Streblus sp* etc. which were both described to be associated with Vesicular and Arbuscular Mycorrhizal Fungi (AMF). The analysis showed that compared to bare soil or rhizosphere soil of other plant species, their rhizospheric soil was characterized by a great diversity of AMF spores and significant activity of soil phosphatase. The most probable number of Mycorrhizal fungi propagules (MPN) in soil was significantly higher in soil colonized by these species. These results suggest that at least one of these selected plant species could be used as a nurse plant to enhance soil fertility for the benefit of upland rice production.

73. Extension of oil palm in altitude under global change in North Sumatra: ecophysiological responses and yield

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Global change effect in North Sumatra has provoked an increase of minimum temperatures (climatic recordings – 1971 until nowadays – station of Bah Butong, 850m; 1971-1990: T°Cmin from 16°C to 18°C; 1990-2008: until 19°C) in some highlands devoted traditionally to tea plantation. This increase has potentiality to benefit to oil palm which has replaced tea since 2006. Today, total area of oil palm in Sumatran Highlands is reaching 4700 ha from 500 to 1000 m. Because oil palm planters have placed a bet on new extension, conditions are still far to reach maximum productivity. There is a need for fine physiological studies to quantify main constraint factor for yield metabolism. Early in 90', some oil palm trials were planted from 250 to 850 m: our main goal was to evaluate this elevation effect on leaf gas exchanges, phenology and yield. Climatic data series have been recorded (1971-2013); photosynthesis and transpiration were measured on 12-year old trees (origin DeliXYangambi), with a portable photosynthesis system (LI-COR 6400[1]) at 3 different altitudes (1)550-580m-(2)650-680m-(3)815-820m completed by individual vegetative and yield observations. Altitude effect was observed on trunk height (34 cm more until 700 m), on petiole thickness (3 times more from 250 to 1000 m). 40 % loss for maximal photosynthesis was observed by elevation of 400 m and 50 % for WUE between 600 and 800 m. Concerning FFB (yield) 25 % loss was observed for 4- to 7-year old trees at 800 m, 40 % for 7- to 10-year old and until 60% (with 10 t FFB) for older trees. Late bunch abortions seem responsible for yield loss. In order to improve sustainable yield in Sumatra highlands, new adapted material, tolerant to low temperature, presenting faster metabolism has to be produced. Innovated and adapted cropping practices (ecofriendly: adapted fertilizer input, new density planting, special pruning, biological control for Marasmius, pollination improvement with elaeidobius) must be applied during new land extensions.

[1] The LI-COR 6400 (LI-6400) utilizes gas exchange principles to measure the photosynthesis rates of plants.

74. Impact of climate on major cereal crops production in Sokoto State, Nigeria

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The study aimed at examining the impact of climatic factors (rainfall, minimum and maximum temperature) on cereals production in Sokoto state, Nigeria. Secondary data from 1997-2008 were used in respect of annual yield of major cereals crops (Maize, Millet, Rice and Sorghum) (t ha^{-1}). Data with respect to climate was collected from Sokoto Energy Research Centre (SERC) for the period under review. Data collected was analysed using descriptive statistics, correlation and regression analysis. The result of the research reveals that there is variation in the trend of the climatic factors and also variation in cereals output. The effect of average temperature change has a negative effect on crop yields. Similarly, rainfall is not significant in explaining the effect of climate on cereal crops production. The study has revealed to some extent the effect of climatic variables, such as rainfall, relative humidity, maximum and minimum temperature on major cereals production in Sokoto State. This will assist in planning ahead the cereals production in the area. Other factors such as soil fertility, correct timing of planting and good cultural practices (such as spacing of strands), protection of crops from weeds, pests and diseases and planting of high yielding varieties should also be taken into consideration to increase yield of cereals.

75. Resource-conserving agriculture for restoring soil productivity and climate change mitigation in northern Ethiopia

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Long-term *in situ* soil and water conservation experiments are rare in sub-Saharan Africa. Resource-conserving agriculture (RCA) that combined *in situ* soil and water conservation local tillage practices (terwah and derdero) with conservation agriculture improved soil quality and crop yield and minimized environmental impacts. A long-term experiment was conducted (2005 to 2013) on a Vertisol to quantify impacts of RCA on runoff, soil loss and crop productivity. The tillage treatments were (i) derdero+ (DER+) with permanent raised bed, ploughed only once at planting by refreshing the furrow and 30% standing crop residue retention, (ii) terwah+ (TER+) with furrows made at 1.5 m interval, plowed once at planting, 30% standing crop residue retention and (iii) conventional tillage (CT) with a minimum of three tillage operations and crop residues removed. Runoff and soil loss were measured in plastic sheet lined collector trenches. Significantly different ($P<0.05$) runoff coefficients (%) and soil losses (t ha^{-1} y^{-1}) averaged over 9 yrs were 14 and 3, 22 and 11, and 30 and 17 for DER+, TER+ and CT, respectively. Further, modeling of the sediment budgets shows that total soil loss due to sheet and rill erosion in cropland, when RCA would be practiced at large scale in a 180 ha catchment, would decrease to 581 t y^{-1}, instead of 1109 t y^{-1} under the current farmer practice. Using NASA/GISS Model II precipitation projections of IPCC scenario A1FI, RCA is estimated to reduce soil loss and runoff and mitigate the effect of increased rainfall due to climate change. A period of at least three years of cropping was required before improvements in crop yield became significant. Adoption of RCA systems in the study area requires further work to improve smallholder farmers' awareness on benefits, to guarantee high standards during implementation and to design appropriate weed management strategies.

76. Millet (*Pennisetum glaucum*)-acacia association for sustainable improvements in agricultural productivity in Niger

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Millet (*Pennisetum glaucum*) occupies two thirds of the agricultural land in Niger and constitutes a major production for food security of the Sahelian countries. This agriculture is carried out under low soil fertility conditions and high variability in rainfall. Tree and cereal association allows working on both aspects. The legume family's trees such as *Acacia senegal* fixed nitrogen and therefore provide increased fertility. The presences of these trees limit evapotranspiration and could have a beneficial effect on cereals growth. However, the shadow limits the cereal crop photosynthesis. Through millet monitoring, we estimated the performance in different areas of interaction under the influence of *A. senegal*. The experimentation was designed in concentric crowns around *A. senegal* where shadow and nitrogen effects can vary: the first crown Z1, near the tree covers half the radius of the crown, Z2 covers the rest of the crown and Z3 envelope on the previous a distance of ½ crown radius represents the witness. Yield estimates are significantly higher in Z2, Z3 and Z1 respectively. Thus, the presence of *A. senegal* in crop fields creates an agroecological environment favorable to the millet production. The advantage of using these interactions is an economic value of trees that provides additional income in the form of gum arabic and wood.

77. Collection of farming address climate changes in the department Kaolack / Senegal

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The climate of a country directly influences the ecological characteristics of its lands, waters and conversely how its inhabitants earn their living and organize their lives (UNFCCC, 2002).
The climate is an essential part of the economic infrastructure in Africa (Boko, 1989). Indeed livelihoods are characterized by the exploitation of natural resources, which is dependent on the climate. Thus, any climate-induced crisis may result in lower revenues and affect the entire rural economy (Boko, 1989). It is for this purpose that Boko 1989, describes the decisive climate of social facts in Africa.
Two types of data were used in this study: (i) climate data and (ii) the data on the perception of the producers of climate variability. Climate data relate to daily data of rainfall, temperature and wind speed. They are from the national climate observing network. This network is managed by the National Meteorological Department (DMN). The first rainfall stations in the network have been installed on the study area since 1921. However, it was in 1950 that the network has become denser. Improving the quality of data that resulted led to the choice of the period 1951-2010 as the reference period for the study of precipitation and temperature. As wind speeds, the study period will also be the same for the 1951-2010 synoptic station Kaolack. Our land surveys have shown that rural populations do not have an advanced level of education. But despite this, we noticed that they have a good knowledge on the perceptions of climate risk. However, they find it difficult to define appropriate accommodation measures and efficient management. Nevertheless, they are involved in agricultural diversification and conversion in the non-agricultural sector, etc., they migrate or are resigned to the worst case.
However, we noted the government's intervention by the institutionalization of agricultural development measures at national level. This will allow the farmer to minimize the loss of agricultural output.

78. Mitigating methane emission in rice ecosystem by drip irrigation

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Rice agriculture is a big source of atmospheric methane, the warm, waterlogged soil of rice paddies provides ideal conditions for methanogenesis, and though some of the methane produced is usually oxidized by methanotrophs in the shallow overlying water, the vast majority is released into the atmosphere. Therefore, the water saving methods in rice crop might reduce methane gas emission. So, the water saving technologies were experimented at Tamil Nadu Agricultural University, Coimbatore, India using ADT (R) 45 rice variety during Summer 2012 and 2013. Methane measurements were analysed in different methods of rice cultivation and irrigation methods such as System of Rice Intensification, Conventional transplanted rice, Aerobic rice cultivation, Subsurface Drip Irrigation (SDI), Surface Drip Irrigation (DI) method. The methane emission was measured in closed chamber technique made up of Acrylic chambers and the collected gas was analysed by using Gas Chromatography. Diurnal variation analysis revealed that methane emission was peak during 10.00 - 12.00 hrs. Time trend analysis showed higher methane emission was observed during tillering to grain filling stages of rice with a range of 3.0 - 7.0 mg m^{-2} h^{-1}. Higher methane emission was recorded in conventional irrigation (1600 kg ha^{-1}) over SRI planting method (1250 kg ha^{-1}) during the entire season. On the other hand, 29.3 per cent lesser methane emission was observed in SDI over surface DI followed by 56.8 per cent over conventional aerobic rice. This is due to soil chemical parameters such as pH, Eh, dissolved oxygen, soil organic carbon content and rice growth parameters such as volume of plant, total dry matter accumulation, root oxidase activity which was more favourable for reducing methane emission in SDI than the other methods of irrigation and planting. Increased methanotrophs population and proper root zone fertigation could be the main reasons for reduced methane levels; better yield with water productivity in Subsurface Drip Irrigation could be recommended for future climate resilient rice farming.

79. Eating more grain legumes and less meat promotes climate smart cropping systems

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The increasing global meat consumption imposes accelerating competition for natural resources and severe environmental problems. Legumes such as beans, peas and lentils provide protein rich and healthy food, have low climate impact and land use demand per unit of edible protein, and reduce the need for nitrogen fertilization via their symbioses with nitrogen-fixing bacteria. Reducing meat production and consumption while increasing the cultivation and consumption of legumes will thus have important benefits for the environment as well as for food security and human health. We used data on land use demand and greenhouse gas emissions related to the current Swedish meat consumption to assess the effects of replacing all imported meat, which corresponds to around 40 % of the meat consumed in Sweden, with domestically grown legumes. Assuming that food legumes cultivated in Sweden produce on average 2500 kg dry grains per ha with 25 % protein, our calculations show that replacing all imported meat with legumes while maintaining the current per capita protein intake would lead to dramatic (around 40 %) reductions in total land use and greenhouse gas emissions. A further reduction of the meat consumption, following the Swedish Food Agency's guidelines to reduce both the total protein intake and the consumption of red meat, would result in additional reductions of land use and climate impact to approximately 50 % of the current situation. Up to 73 000 ha of arable land would be required for the increase in domestic legume cultivation in the replacement scenario. This implies nearly a three-fold increase of the area currently used for cultivation of grain legumes in Sweden, but is still low compared to the almost 900 000 ha used for Swedish cereal production. The projected increase in grain legume cultivation would lead to a diversification of Swedish arable cropping systems and have large benefits for food system sustainability.

80. Acacia catechu trees in rice fields: a climate smart traditional agricultural system of Northern Bangladesh

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Indigenous land-use systems can provide valuable information for the design of ecologically sustainable and socially acceptable climate smart agricultural system. One such traditional system is the growing of Acacia catechu trees, locally known as khoir, in rice fields of smallholder farmers in northern Bangladesh. The functional characteristics of the system were collected through participatory rural appraisal involving intensive interactions with farmers and through a semi-structured-questionnaire survey in 20 villages, involving a total of 100 farm families. The farms had an average of 33 khoir trees, ranging in age from <1 to 35 years, per hectare in cropland Agroforestry type of rice fields, the tree-stand density being greater on smaller than on larger farms (>8 ha). Over a 15-year short rotation period, the trees provide a variety of products such as fuelwood (25 kg/tree), brushwood for fencing (6 kg/tree), small timber for farm implements and furniture (0.1 cu.m), and non-wood products such as katha, guti khair (used as dye in textile industries) and pitch khoir (eaten by people during chewing of betel leaf (Pan). Khoir trees account for nearly 20 % of the annual farm income of smallholder farmers (<2 ha). By practicing the climate smart traditional Agroforestry type of Agricultural system (rice + Khoir), farmers can get higher cash returns on a short term (15 yrs) harvest cycle of trees, and the labour input (both family- and hired) on farms was distributed more uniformly throughout the year than in rice monoculture. Purchased inputs are seldom used in the system. The ease of management of the system, the self-generating, robust and wind breaking nature of the tree and the multiple products and services it provides are the major factors that encourage farmers to adopt the system. More detailed investigations are warranted to provide insights into farmer adoption of climate smart Agricultural system in other parts of the tropical region.

81. Soil carbon sequestration under traditional management of smallholder's oil palm plantations in Sudano-Guinean context

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In the current context of climate change, oil palm plantations are much criticized because they replace large areas of tropical forests. In Benin Republic, located in the Sudano-Guinean region, smallholder's oil palm plantations do not replace forests but old and unproductive croplands. In some of these palm plantations, pruned leaves from the palm trees are deposited to the soil for recycling. A study was conducted in southeastern Benin to evaluate the effect of the input of pruned leaves on soil carbon sequestration in smallholders' plantations. The study area is characterized by a mean annual precipitation in the range 1300-1400 mm. Soils are slightly desaturated ferralsols. Young palm plantations (4-6 year-old), pre-adults (7-12 year-old) and adults (13-20 year-old) were selected. In the young plantations, the leaves pruning is not occurring yet. In the pre-adults and adults plantations, the leaves have been cut down and recycled during respectively 4 years and 10 years, and are totally returned to the soil (TR) on the planting lines and not returned (NR) in the interrows. Nine palm trees were selected in each plantation to estimate the biomass of leaves on the soil surface and the carbon stock in the 0-20 cm soil layer. Leaves biomass amounted 45 and 80 Mg of dry matter per hectare, respectively for pre-adult and adult plantation, corresponding to 22 and 38 Mg C.ha^{-1}. The soil carbon stock in the top 0-20 cm soil layer increased significantly after 10 years of leaves deposits (18.4 Mg C.ha^{-1}) compared to young plantations (16.2 Mg C.ha^{-1}). In the study context, smallholder's oil plantations play a role for greenhouse gas mitigation through the soil carbon sequestration.

82. Impact of climatic variables on rice yield in Bangladesh: a spatio-temporal analysis

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Climate change may impact on rice food security in many parts of the world including Bangladesh. Bangladesh may lose nearly 28 percent of total rice production due to climate change. Rice is the main staple food of Bangladesh which covers 70 percent of direct calorie intake. In addition, 77 percent of agricultural land is used for rice cultivation in Bangladesh. Presently, Bangladesh has 150 million people. Further, 75 million people will add to this number by 2050. Country needs sufficient rice production to feed huge number of people. The relationship between climatic variables and rice yield has become an important indication to assess if any changes of rice yield may occur due to climate changes. But little attention was given to understand climate impact for different varieties at various regions in Bangladesh. Against this backdrop, the main aim of this paper is to analyse effects of climatic variables on rice yield. Study analysed 30 years (1981 to 2010) of spatial and temporal variation of climate-yield relationship for three rice varieties including 21 former districts. Multiple linear regressions were used to see climate change association. The resulted R^2 of each rice variety indicated that variation in different rice yield varieties was possible to explain by climatic variability. Moreover, impact differs for different varieties as Aus and Aman varieties became more susceptible compared to Boro for climate change. Some of the variations in rice yield are related to climatic variability, but a large proportion of the variance is related to district characteristics. It might depend on other issues like, biophysical conditions or management of rice cultivation in different districts. Further spatial analysis is needed to see influences of bio-physical and management practices on rice yield at different districts in Bangladesh with climate change.

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L3.3 Climate-smart livestock

83. Productivity and mitigation effects of alternative feeding practices in smallholder dairy farms in the north of Vietnam

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We investigated the impact of alternative feeding practices on productivity and emissions of smallholder dairy systems in Vietnam. The study was conducted in two phases. During the first, data was collected in 30 farms in the North of Vietnam through a semi structured questionnaire. Mean size (± SD) of the farms was 0.85 ± 0.50 ha (15% crop area) and ~ 9 head of pure and crossbred Holstein Friesian cattle. Herd structures consisted of 11, 25, 17 and 47% of calves, heifers, dry and lactating cows. Annual milk yield/farm was 28,655 ± 16,035 L (~US$ 20,059). Daily milk yield/cow was 14.1± 2.9 L. Using the feed supplied in each farm, the Ruminant model estimated yearly emissions of 590 ± 359 kg of enteric methane/farm, 14.8 ± 8.99 ton CO_2eq/farm and 0.52 ±0.14 kg CO_2 eq/L/milk. In the second phase, data was computed using a fixed representative farm to estimate responses to different feeding practices. Results showed that manipulating concentrate level in the diet can increase milk yield up to 31% with reduced methane efficiency (kgCO_2eq/L potential milk from ME) up to 16%. Compared to elephant grass (*Penissetum purpureum*) and guinea (*Megathyrsus maximus*) grasses or maize (*Zea mays*; 50% DM of the diet), the use of ruzzi (*Brachiaria ruziziensis*) grass improved milk yield up to 14% and reduced methane efficiency up to 9.4%. Potential increase of milk yield (5.3%) and decreased methane efficiency up to 3.6% were predicted when maize silage substituted 50% of the elephant grass. This evaluation demonstrates that feed efficiency under the current development of the Agricultural Synergies NORAD project can improve productivity and the environmental protection of the dairy sector in Vietnam.

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84. Building climate smart pastoralism in the Sahel: ways forward

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The critical triptych (food security-adaptability-mitigation) that ensures climate smart agriculture is not really reached in Sahelian pastoralism. The major shock remains spatiotemporal variability of rainfalls and temperatures. Deficits that followed 1970s lead to a severe drought that cruelly affected the mixed/lower mobility production systems (100,000 people and third of the cattle died) reverting to a higher mobility system. This appears to be the most effective strategy to sustain pastoralism as the second large-scale drought occurred in 1984 was less destructive. However, the direction of temperature and precipitation change remains unknown especially in Western Africa (Schellnhuber *et al.*, 2013) thus reinforcing global uncertainties in which live pastoralists. Beyond climate variability, Sahelian herders are increasingly confronted to other shocks (commodity price variability and transmission, sanitary risks with re-emerging diseases, misused zoo-sanitary agreements and conventions on cattle marketing and transborder transhumance). Therefore political, socio-economic and ecological events all affected the increasing vulnerability of pastoralists. To build a climate smart pastoralism, it is crucial to integrate uncertainty in the outcomes of improved options (Jeuland and Pattanayak, 2012) and social, economic, political and institutional aspects into diagnosis and resolution of climate change impacts (Wane *et al.*, 2014).
Empirically, we focus in Senegal Sahel with a survey that showed pastoral population strategies before and after the establishment of boreholes in 1956 in changing production systems and mobility schemes. A different history is told according to different sub-steps characterized by climate and economic crises, deregulation of agricultural sector, upgrading and rehabilitation of the livestock sector and food crises.

85. Climate and animal diseases: the case of 2009/2010 rift valley fever outbreaks in South Africa

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Climate change is viewed as one of serious threats to livestock production due to emergence of animal diseases that are associated with higher temperatures and changing rainfall patterns. During 2009/2010, South Africa experienced varying episodes of Rift Valley fever (RVF). RVF is a viral zoonotic disease spread by infected mosquitoes and characterised by high rates of abortion and neonatal mortality, primarily in sheep, goats and cattle, but also in exotic and wild animals. These outbreaks were associated with heavy summer rainfalls that the country experienced earlier. With about 80% of agricultural land in South Africa, mainly suitable for extensive livestock farming, livestock farming plays a vital role as a source of livelihood for many rural communities.

The aim of the study was to estimate the value of vaccination in order to justify the amount of additional research that should be budgeted to develop newer and more effective vaccines for the control of RVF. A farm survey was conducted to obtain primary data, and a questionnaire was administered to 150 farmers in the Eastern Cape, Northern Cape and Free State Provinces of South Africa. A deterministic economic model was used to conduct a financial cost analysis of the RVF outbreaks. The total revenue losses in the three provinces were estimated at R238 million, farmers in the Northern Cape incurred R174 million (73%) followed by those in Eastern Cape at R50.9 million (21%) and those in Free State at R13.0 million (5%). A t-test to compare independent sample means was used to estimate the value of vaccination during the outbreaks. The average revenue losses incurred by farmers who did not vaccinate all their livestock were estimated at R50 726 which is double the R24 377 loss incurred by farmers who vaccinated all their livestock.

86. Cattle ranching in the Amazon: quantifying synergies between intensification, mitigation and profitability

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Thanks the recent zero-deforestation policies, cattle ranching systems in the amazon are engaged in an intensification process, in order to produce more beef or milk in a smaller pasture area. A large set of new practices in the farms, especially about cattle alimentation and land-use diversification, potentially change the environmental footprint of the activity. However, no system or large experiment are available in the region, to evaluate and monitor these gains in terms of emissions and energy balance, for this activity historically responsible for large deforestation, emissions and natural resources waste.

The authors present in this paper a three-year research results, adapting a European analytic tool, able to quantify at the farm scale the GES emissions, the energy balance, and the gross margin (Planet method). After parameters and conception adaptations, the tool has been applied in 35 farms in a Paragominas region, state of Pará, Brazil, known for the "green livestock dynamic". The sample is representative of the diversity of farms, in terms of size, livestock systems and intensification level. The results show the large difference between the traditional extensive systems, and the innovative practices. They indicate what kind of practices allow the best trade-off between intensification and environmental footprint, to optimize the use of ecosystem resources like water, solar energy, trees and organic matter in the soil. These results can be used to identify efficient intensification and mitigation pathways, relative to the farm diversity, as discussed in this communication. In conclusion, authors explain that the innovative process for mitigation should be monitored at the landscape or jurisdictional level, in complement to the farm level.

87. Potential multi-dimensional impacts and tradeoffs of improved livestock feeding scenarios in Babati, Tanzania

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Two-thirds of smallholders in eastern and central Africa rely on mixed crop-livestock systems as a source of income and nutrition, for farm productivity, and as an asset. Rising population pressure leads to diminishing farm sizes, increased food-feed competition and soil fertility depletion due to disappearance of grazing areas, fallows and rotations. Such pressures, in combination with increasing climate variability put the livelihoods of millions of smallholders at risk. At the same time, livestock production in East Africa has one of the highest greenhouse gas (GHG) emission intensities and lowest feed use efficiency worldwide. Improved livestock feeding has been highlighted as one of the most promising climate-smart agricultural (CSA) option for these systems, contributing to increased crop-livestock productivity while also mitigating GHG emissions and adapting to climate change. While previous studies have mostly quantified single measures of whole-farm performance (*i.e.* income), in this study we quantify the potential impact of livestock feeding scenarios on multiple socio-economic and environmental performance indicators and their tradeoffs. Representative farms from Babati, Northern Tanzania are assessed with the whole farm model FarmDESIGN which has been extended with a GHG module. Calculations are mainly based on IPCC tier 2 methods, while CH_4 from enteric fermentation is estimated with the Ruminant model (tier 3 method). Participatory livestock feeding scenarios were developed together with farmers and livestock extension workers. Preliminary results underline the importance of such potential multi-dimensional impact estimations for prioritization of CSA interventions. A 1 ha farm with mixed cropping (maize, bean, pigeon pea, sunflower and sorghum) and livestock activities (11 cattle, 15 goats and 10 chickens) emitted 1863 kg CO_2-equivalent ha^{-1}, with 36% from enteric fermentation and 48% from change in soil organic carbon. Improved livestock feeding combined with sustainable land management could significantly decrease these GHG emission intensities.

88. Towards climate smart dairy cattle in Rwanda: mapping feed resource potential under climate and land use scenarios

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With a burgeoning agrarian population; declining per capita land holding and an ambitious "one cow per poor family livelihood and nutrition program", Rwanda needs a robust feed resources development strategy that responds to the challenges of global warming and sustainable food futures. A study used different geo-spatial tools and country statistics to estimate productivity value per area of land use for high, mid and low altitudes of Rwanda. Livestock Analysis Model (LAM) was also used to estimate methane emissions associated with the production of milk and meat to meet the demands of an increasing population. Preliminary results revealed that grazing land that was covering nearly 4000 km^2 in 1990 has been reduced by 25%. Crop residues showed the potential to sustain a 5% annual increment of tropical livestock units (TLU) of ruminant livestock if effectively utilized. Three to six percent of cropped land can be used for fodder production using hedge rows. Currently nearly 60% of terraces are effectively covered by fodder crops or shrubs, with annual increment of 5% of terracing with half of grazing land preserved. Environmental costs associated with enteric methane emission would be reduced by approximately 26% by aggressive policy that foster genetic improvement and rational land use in feed resource development.

89. Protein supplementation improves saline water utilization in lambs

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Access to good quality water is a globally growing problem. The growth of livestock in recent decades, especially in the Southern Cone, has increased competition for freshwater directly impacting the availability for other uses. In the coming years, the generation of technologies to maintain or increase beef production with lower quality resources is a guaranteed challenge. Therefore, an experiment was conducted to evaluate increasing levels of dietary protein as a strategy to improve the use of water with high saline tenors. Twenty lambs in individual metabolism cages (BW= 31 ± 4 kg; n = 4) were used in a ten treatments by two period (10 × 2) trial. Treatment structure was 2 × 5 factorial. First factor was water quality (WQ): low salt water (LS; 700 mg/kg of total dissolved solids [TDS]) *vs.* high salt water (HS; 10,000 mg/kg TDS). Second factor was 5 levels of soybean meal (SBM; 44.4% CP) 0, 0.25, 0.50, 0.75 or 1.00% BW/d. The basal diet consisted of tropical grass hay (*Panicum maximum* cultivar Gatton; 7.0 % CP). After 15 d of adaptation to treatments, periods consisted of 5 d for dry matter (DM) and water intake (WI) determination. Supplemental SBM × WQ interactions were significant ($P = 0.05$) for forage dry matter intake (FDMI) and total dry matter intake (TDMI), but not for WI ($P = 0.60$). At levels of 0.5% or higher of SBM, there was no statistical difference for FDMI and TDMI. Water intake increased linearly ($P < 0.01$) in response to SBM. According to our experiment it is concluded that high levels of SBM supplementation allowed making a more efficient use of saline water, enabling increasing productivity in environments with limited resources.

90. An optimal live-weight gain in winter improves growing performance and reduces CH_4 in tropical beef cattle systems

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The objective of this study was to access the impact of winter growing rate on global stocker performance and methane (CH_4) emission in beef cattle in the subtropical dry Chaco of Argentina. Two hundred twenty eight male and heifer Braford calves (BW: 182 ± 37 kg; 6 mo. old) were assigned to four winter treatments to evaluate the effect of winter animal performance on summer or overall growing rate and to estimate CH_4 emission on grazing Guineagrass (*Panicum maximum*). In this study, treatments were made to produce a wide range live-weight gain in winter: (1) ad libitum access to low-quality Guineagrass hay plus protein supplementation, 2) idem treatment 1 plus energy supplementation, 3) limit fed high concentrate diet to achieve a gain of 0,7 kg/d, and 4) ad libitum corn-silage diet. Immediately after winter phase (yr-1:130 d and yr-2: 87 d), steers grazed Guineagrass pasture during the summer season. The relationship between ADG in winter (wADG) with summer (sADG) and global (*i.e.*, both winter and summer; gADG) ADG as well as the association of wADG with CH_4 losses were analyzed using the PROC REG of SAS. Summer and global ADG fitted to the following quadratic regressions: sADG (g/d) = 451 (P<0.0001) + 0.279 wADG (P=0.0153) – 0.000447 (P<0.0001) (wADG)2 (P<0.0001) [R2 =0.3283; P<0.0001], while gADG (g/d) = 229,84 (P<0.0001) + 0.6462 (P<0.0001) wADG – 0.000258 (P<0.0001) (wADG)2 [R2 =0.7013; P<0.0001]. The relation between CH_4 emission per kg of liveweight gain fitted to the following quadratic regression CH_4 in summer (MJ/ kg of LW gain) = 18.26 (P<0.0001) – 0.02514 (P<0.0001) wADG + 0.0000398 (P<0.0001) (wADG)2 [R2 = 0.5255; P< 0.0001]; and global CH4 (MJ/ kg of LW gain) = 25.64 (P<0.0001) – 0.03138 (P< 0.0001) wADG + 0.0000156 (P<0.0001) (wADG)2 [R2=0.6314; P<0.0001]. In conclusion, an appropriate rate of gain in winter might maximize summer and overall live-weight gain minimizing overall CH_4 emission.

91. Global farm platforms for sustainable ruminant livestock production

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We are at a crucial time for livestock agriculture when the response to international imperatives for both maximizing production and minimizing pollution on a global scale has led to the development of sustainable intensification. However, farming systems vary widely in their inputs and outputs, environmental consequences and product quality, and need to be understood in the specific context where they will be used. Ruminants make an important contribution to global food security as they convert feed that is unsuitable for human consumption to high value protein, demand for which is currently increasing at an unprecedented rate. Sustainable intensification of ruminant livestock may be based on either pastoral grazing systems, or feedlot and housed systems utilising cereal and forage based diets. However, both approaches have associated risks such as water and air pollution, carbon emissions, soil degradation and erosion, reduced fertility and production efficiency, animal welfare and product quality issues. These challenges are multidisciplinary and highly applied, necessitating solutions that can be properly explored, implemented and tested in real-world production systems. To this end we have developed a global network of 'farm platforms' across different climatic and eco-regions as a crucial resource for optimising and exemplifying research on the contribution of sustainable ruminant livestock production to global food security (www.globalfarmplatform.org). Decisions focus on the production system, appropriate animal genetics and nutrition, optimising soil, plant, animal and human health and ensuring livestock production does not have negative impacts on welfare, ecosystem services or biodiversity. The network allows key metrics across a range of production enterprises to be quantified and assessed for adoption of best practice through national outreach programmes.

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92. Climate change, livestock productivity and poverty: empirical evidence from south Asian countries

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Rural economy in developing countries critically depends on livestock recourses. In recent years, the changing climatic conditions have significantly affected the production and yield of livestock resources. Using a comprehensive data collected from farmers in three south Asian countries such as Nepal, India and Bangladesh, the present study makes an attempt to assess the impact of climate change on livestock production and household poverty by employing the propensity score matching (PSM) approach. This approach is used to correct for potential sample selection biased ness that may arise due to systematic differences between the farmers with climate change experience and those without experience. The PSM analysis was carried out by employing two different matching algorithms *i.e.* nearest neighbor matching (NNM) and kernel based matching (KBM). The empirical results indicated that due to climate change the livestock productivity has decreased substantially and as a result the household income level has decreased while the poverty level has gone up. In order to negate the adverse effects of climate change farmers have adopted a number of climate mitigating strategies like livestock insurance, selling of livestock and also allocation of more area under fodder.

93. Solutions for greenhouse gases mitigation in ruminant farming: how to favor their adoption?

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This paper overviews mitigation perspectives in ruminant farming systems and discusses main obstacles and levers for their adoption. Using dietary lipids or nitrates as feed additives are the two most efficient ways for reducing enteric methane emission without affecting animal performances. However fat use in diets is often expensive and the use of nitrates may be not acceptable by farmers and/or consumers. In the future, genetic selection for low-emitter animals and progress in manipulating rumen microbial ecosystems are two promising ways of progress. Decreasing dietary protein of dairy cows will reduce N excretion and thus nitrous oxide emissions. Improving animal reproduction performances and health through more robust animals and decreasing age at first calving will reduce emissions, possibly resulting in a lower level of production. Increasing carbon sequestration through improvements in pasture management and using legumes in grassland in replacement of mineral fertilizers are considered as win-win strategies; they are not applied currently at large scale because many farmers are not convinced they are sound. Optimizing manure management is an interesting mitigation option, but requires investments. At least, using sexed semen or dual-purpose breeds rather than specialized breeds to better valorize male calves for meat may be solutions for the future, but these strategies will significantly affect dairy and meat chain organization. Larger emission reductions will be achieved by using several options simultaneously. In that context, the last section uses the key reading of the public economics theory to define the principles of a public policy aiming at efficiently reducing GHG emissions from ruminants: this policy should combine transitory direct aids for facilitating adaptation and the internalization of carbon price in production costs of farmers; it should also target research, agricultural advice as well as farmers' education and organization.

94. Perception of climate change and adaptation of herd conduct mode in Burkina Faso during rainy season

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In Sub-Saharan Africa, livestock breeding is traditional, characterized by the exploitation of natural pasture. In the context of climate change and increased uncertainty of rainfall, breeders adapt herds conduct modes on pastures to maintain acceptable levels of production, and to build resilience of their agricultural system. An investigation realized with 30 breeders distributed over 3 climatic areas in Burkina Faso (Sudano-Guinean (Folonzo), Sudanese (Koumbia) and Sudano-Sahelian (Dédougou)) showed that they had a perception of climate change from 10 to 15 years ago, manifested by decreasing order of importance:

- By a delay of 1 to 2 months of rains installation (more important in the south);
- By an increasing of the length of « drought pockets » of 10 to 20 days (more important in the north);
- And to a lesser extent by an increase of the rainfall in August and finally an early stopping of rains (shorter in the north).

The main cause of these changes would be, according to them, the expansion and advancement of agricultural front.

Face to this evolution, breeders adapted the conduct modes of herds:

- In case of delayed rains, they split the herd in two with a transhumant lot, proceed to food shopping and move temporarily the herd towards a more watered area;
- In case of prolonged or repeated drought pockets, they conduct herds in swampy areas, better provided into herbaceous pasture;
- In case of heavy rains in August, herds are conducted on hills, times of staying in muddy parks are reduced and sanitary treatments increase;
- In the event of early stopping of rains, a short transhumance is anticipated in areas where annual herbaceous remained green and retained their food value.

Adaptations of climate change is different with the agro-climatic area (largest storage of the fodder in the Sudanese and Sudano-Sahelian area), but also with the size of the herd (more food and fodder stock in the medium size herds) and locally available resources (short transhumance facilitated by the presence of free space without cultivation).

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95. Mini-livestock ranching – raising climate-smart insects for nutrition and livelihoods

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Entomophagy, or edible insect species for human food and animal feed, is a widespread informal practice for approximately 80% of the world's population. Insect species can produce significantly less greenhouse gas emissions compared with cattle, pigs and chickens and have similar nutritional profiles.

Edible insect species also have a much lower feed to meat ratio compared to traditional livestock. For example, domestic crickets require ten times less feed than cows to produce the same amount of meat. Some insects can eat foods that are otherwise waste, including vegetables and fruit no longer suitable for human consumption, or by-products from beer production and even abattoir wastes. Most insect species can be raised on small areas of land and their total water needs are almost negligible, particularly when compared to animals consuming grain feeds.

Edible insect consumption is particularly strong in countries in the global south. In Central America, tropical regions of South America, South East Asia and Southern Africa, edible insects make up a high proportion of diets in particular during seasons of insect harvest. Countries in these regions are also facing the most challenges from climate change and the need to adapt agricultural practices.

While entomophagy already plays an important role in human and animal diets on a seasonal basis through collection in the wild, there is an untapped potential to increase access to this nutritious, climate-smart food via intensified semi-cultivation and raising insects in farming environments.

Enabling people to increase reliance on edible insects is a climate-smart intervention that could also be a significant source of income, particularly for women and girls, who in many places are the majority of those collecting and selling insects. During times of insect harvest, price per kilogram of insects often exceed that of conventional meat.

These arguments will be supported with examples from Thailand, Mexico, and Ghana.

96. Evaluating animal mobility in relation to climate change mitigation: Combining models to face methodological challenges

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Pastoral farming systems are likely to adapt to climate change through animal mobility and thus the potential of available forage resources depending on the season. However, the role of animal mobility in mitigation strategies is not yet known. To understand its role, we investigated major methodological challenges: (i) we addressed the diversity of grazing areas and forage resources mobilized by these systems to estimate methane enteric emissions; (ii) we analyzed the functioning of farming systems based on various combinations of resources use in relation to the assessment of their GHGs and energy requirements (iii) we assessed the impacts on soil and biomass carbon flows caused by grazing practices (carbon sequestration/emission). We developed a methodology based on existing models (OSTRAL and CASA) that we adapted and used in combination. This method was applied to four French Mediterranean farming systems that used mobility differently. Results from OSTRAL model showed that two systems improved efficiency. In the first system, using great quantities of grazing resources from natural areas reduced GHG emissions. In the second system, high animal productivity balanced the increase in GHG emissions caused by feed production. Moreover, CASA model can simulate scenarios of land cover dynamics in natural environments used for grazing. It will help us to assess the impact of grazing practices and thus carbon flows in systems in natural environments. To conclude, this first application shows that the practice of animal mobility off the structural limits of the farm seems engaging to reduce GHG emissions and to improve energy balance.

97. Substitution of maize silage with barley silage in dairy cow diet as mitigation strategy: effect on milk quality

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Water is becoming a restricted resource. That is critical for the Po valley, agro-livestock system, based on maize production requiring large amounts of irrigation water.
In the Po Valley this crop finds optimal condition, mainly due to the high summer temperatures and the great supply of irrigation water.
Autumn-winter cereals could represent a partial or total alternative to maize because they require little or no irrigation water.
Cheese production can be affected by dairy cow feeding, so it is crucial to investigate a system based upon barley silage, while maintaining animal performance.
The aim of this study was to evaluate the effect of a partial (Trial 1) or a total (Trial 2) maize silage substitution with barley silage in dairy cow diets on milk yield and composition and on production and characteristics of Grana Padano cheese.
Twenty Italian Friesian cows, chosen among 80 animals, were blocked according to parity, DIM and milk yield before the start of the trial and were divided in two groups. Two trials were carried out according to a change-over 2x2 design with two periods of 4 weeks each. In Trial 1 the treatments were maize silage (MS1) and barley silage+maize silage (BS1), whereas in Trial 2 the treatments were maize silage (MS2) and barley silage (BS2) as forage source.
The partial and total maize substitution with barley had no effect on milk yield while milk fat percentage and milk urea content increased. Milk fat content was higher in BS1 than in MS1, while no difference was observed for milk lactose and protein contents, milk fat and protein yields, fat corrected milk 4%.
In both trials, weight of Grana Padano wheels and milk quality attitude to cheese production were not influenced by the feeding treatments. In trial 1 one wheel MS1 differed for hardness, elasticity and friability in respect to the other wheels. There was no difference among wheels in trial 2.
The study evidenced that use of barley silage is as suitable as maize silage for Grana Padano DOP.

98. Towards climate smart livestock systems in Tanzania: assessing opportunities to meet the triple win

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Climate change is expected to have significant negative impact on livestock production systems especially in sub-Saharan Africa, where livestock play an important role in the livelihoods of many rural communities. Furthermore, livestock systems in this area are characterised by poor performance, which results in low herd productivity and high emissions intensity. The reasons of this are mainly associated with poor feed quality, which in turns determines low digestibility, and poor animal health. These problems can be tackled by improving forage quality and by using low inputs breeding strategies.

This paper quantifies the potential synergies and trade-offs between the three pillars of CSA of adopting improved feeding practices and livestock breeds in Tanzania. We draw on household surveys, stakeholder feedback, livestock and economic modeling tools. We use RUMINANT model to assess sustainable intensification alternatives to the current base system (local cattle and grazing of maize residues), such as: i) improved Napier + maize bran + concentrates; ii) improved Napier + more maize bran + more protein concentrates; iii) improved cattle + improved Napier + more maize bran + more protein concentrates. We use the Trade-Off Analysis Model for Multi-Dimensional Impact Assessment (TOA-MD) to compare different scenarios at households' level and different sustainable intensification alternatives. Our results indicate that all the assessed scenarios lead to increase in milk production (up to 38% with respect to the baseline) and reduction in emissions (up to 20% respect with respect to the baseline), and positive net returns. Further research is needed to understand how to potentially up-scale these results. Yet, barriers to adoption will play a major role on the uptake of the tested practices. This suggests the importance of addressing current barriers of adoption of those strategies that expose farmers to risks and costs.

99. Predicting effects of cattle growth promoting technologies on methane emissions using TAURUS ration formulation software

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Beef cattle contribute to global warming by releasing methane (CH_4) gas through enteric fermentation. The amount of CH_4 produced by beef cattle is largely a function of feed intake and chemical composition of the feed. TAURUS is a beef cattle ration formulation and performance prediction computer program that predicts CH_4 emissions. Climate change effects on cattle intake and heat production and animal maintenance energy are accounted for by TAURUS. This gives the user of TAURUS a tool to formulate several least cost rations and the option to select one with low methane emission. Methane emission is calculated using the diet's gross energy, dry matter (DM) intake, and body weight. Body weight is provided by the user, but gross energy and DM intake are calculated by TAURUS. We estimated the effects of growth promoting and nutrient partitioning agents on performance and CH_4 production in feedlot cattle. For Angus crossbred steers, TAURUS predicted (over the entire feeding period) and observed (13 d prior to slaughter) CH_4 emissions (g per d) were 207 and 266 for controls; 202 and 239 for those fed 33.1 mg monensin and 12.2 mg tylosin phosphate per kg DM; and 209 and 273 for those fed monensin and tylosin phosphate and implanted with 120 mg trenbolene acetate and 24 mg estradiol, respectively. Thus, the TAURUS predicted effects of the growth promoting technologies were similar in direction to those observed—CH_4 emissions were reduced for monensin/tylosin and increased for steroidal implants, but of smaller magnitude. The results can help beef cattle producers to implement dietary strategies to decrease CH_4 emissions from cattle. Mitigating CH_4 losses from cattle will result in a long-term environmental benefit by decreasing agriculture's contribution to greenhouse gas emissions.

100. Farm scale greenhouse gas budget; grazing is smart

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Full farm-scale greenhouse gas (CO_2, N_2O and CH_4) budget of mowing, grazing and feeding management in a livestock system (cattle) was estimated in Hungary to identify mitigation options (Bugac). Grassland CO_2 flux was measured with eddy covariance technique on grazed (0.34 cattle ha^{-1}, 2003-2013) and adjacent mowed (cut once per year, 2011-2013) sites. Soil N_2O flux was measured with chamber technique on grazed and mowed sites. Soil CH_4 flux was measured with chamber technique on grazed and mowed sites. Animal CO_2 respiration, manure and enteric CH_4 emission calculations were based on herd (374 livestock unit) and management (206 grazing and 159 feeding days) and literature data (13 kg daily dry matter uptake, 62.5% of dry matter carbon uptake respired as carbon, 4% of ingested carbon emitted as CH_4 from enteric fermentation). Lateral carbon flux was estimated from farm management data (47 livestock unit exported and 535 t of carbon imported as forage per year). Average net ecosystem exchange was -109±106 g C m^{-2} year^{-1} for grazed and -61±47 g C m^{-2} year^{-1} for mowed site (both sinks). Net carbon storage was 81±52 g C m^{-2} year^{-1} under grazing and -33±26 g C m^{-2} year^{-1} under mowing (by convention positive value means carbon gain by the ecosystem). Net greenhouse gas budget for grazed was 42±58 g CO_2-Ceqv m^{-2} year^{-1} (sink) and -38±26 g CO_2-Ceqv m^{-2} year^{-1} for mowed site (source). At farm level (grazing, mowing, feeding) the net carbon storage was 56±24 g C m^{-2} year^{-1} and the net greenhouse gas budget was 11±26 g CO_2-Ceqv m^{-2} year^{-1}, which were not significantly different from zero. The system should sequester at least 134 g CO_2-C eqv. m^{-2} year^{-1} to offset the greenhouse gas effect arising from the present management at the farm level. We conclude that prolonged grazing periods should be favored instead of mowing in terms of farm scale GHG balance. Warmer winters extends the grazing period, further favoring grazing management.

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101. Effect of ambient temperature on lactating sows, a meta-analysis and modeling approach

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Because of their intense metabolism, lactating sows are highly sensitive to high ambient temperatures, which induce a reduction in their voluntary feed intake and milk production. This also results in an increase in mobilization of body reserves, which may impair reproduction after weaning, and a decrease in piglet weight gain. In the context of climate change which increases the frequency of periods of heat stress, the aim of this work was to quantify the relationships between ambient temperature and sow and piglet performance, and to use these relationships in a prediction model of nutrient utilization by sows. A database with 46 publications and 254 observations was built in order to adjust prediction equations for different criteria such as feed intake, respiratory frequency, body temperature, litter growth, and milk production. These equations were then incorporated into a simulation model including (i) a bioclimatic module predicting the effect of outdoor temperature on the indoor temperature perceived by the sow and (ii) a nutrition module predicting the effect of temperature on feed intake, milk production, energy and amino-acid utilization, and body reserves. This enabled a decision-making tool to be developed for the prediction of performance and nutritional requirement of lactating sows in different climatic conditions. The model was used to simulate the effect of climate on sow's and piglets' performance using climator climate database for West and South France. The results show significant effects of season and region on animal performance and nutritional requirements. The simulations performed for years 2045-2050 indicate that these effects tend to become more marked with climate change. In practice the model developed should enable feed composition to be better adapted to the season and to the geographical location of farms and to expected changes of climate for the future.

102. Greenhouse gas and ammonia emissions from ceramsite covered compared with uncovered during dairy slurry storage

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Dairy slurry storage before field use is the major liquid manure management practice in China, however, air emissions including methane, nitrous oxide and ammonia would occur during the slurry storage period. The goal of this study was to compare greenhouse gases (CH_4, N_2O) and ammonia (NH_3) emissions from a dairy liquid slurry under conditions of covering of lightweight (a cover made of expanded clay aggregate was used) with uncovering conditions, and their temporal variations at different seasons. A commercial dairy cattle farm was chosen for this study. The manure was daily collected and solid-liquid separated, the liquid slurry was pumped into the lagoon for storage, while the solid manure was used as raw material for composting. A lagoon which was about 200 m length, 50 m width and 3.5 m depth was chosen for this study, two area were separated; one area was covered with a depth of about 5 cm of ceramsite while the remaining area was without cover, the gas emissions were measured with the dynamic chamber method with three replications, gaseous concentrations were measured using a multi-gas infrared photoacoustic analyzer with multi-channel sampler; fresh air supply (VR) was measured with flow meters, the gas emission rate was computed from the VR and gases concentration. Slurry and air temperature were monitored using a HOBO temperature sensor and data logger, the slurry was sampled both at inlet and outlet for carbon and nitrogen properties analysis, five days were selected for continuous measure for each season. The result showed that for all gas emissions strong diurnal variations exist in different seasons, highest CH_4 and N_2O emissions were found in the spring season, while the highest NH_3 emissions were found in the summer season, and the ceramsite cover could only reduce NH_3 emission. The annual average CH_4, N_2O and NH_3 emissions were 143.1±124.5g/m^2/d, 118.9±79.6 mg/m^2/d and 633.0±317.6 mg/m^2/d for uncovered storage, respectively, while the annual average CH_4, N_2O and NH_3 emissions were 139.7±117.9 g/m^2/d, 109.7±118.3 mg/m^2/d and 594.1±301.4 mg/m^2/d for ceramsite covered storage, respectively. The results of this study will contribute to the development of gas emissions inventory for manure management and mitigation practices.

103. Grass-legume mixtures enhance nitrogen yield over a wide range of legume proportions and environmental conditions

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Global food security is currently challenged and requires sustainable intensification of agriculture through more efficient use of nitrogen (N) and increased protein self-sufficiency through home-grown crops. Focusing on grassland-based livestock-production, such challenges were investigated in a European continental-scale field experiment conducted over three years at 16 sites that spanned a gradient of climate from Atlantic to continental and from temperate to arctic. The amount of total nitrogen yield (N_{tot}) and the gain of N yield in mixtures as compared to grass monocultures ($N_{gainmix}$) was quantified from four-species grass-legume stands with greatly varying legume proportions. Stands consisted of monocultures and mixtures of two N_2 fixing legumes and two non-fixing grasses. The amount of N_{tot} of mixtures was significantly greater ($P \leq 0.05$) than that of grass monocultures at the majority of sites in all three years. N_{tot} and thus $N_{gainmix}$ increased with increasing legume proportion up to one third of legumes; higher percentages of legumes did not result in a further increase in N_{tot} and $N_{gainmix}$. Thus, across sites and years, mixtures with one third proportion of legumes had 57% higher N_{tot} than grass monocultures and attained ~95% of the maximum N_{tot} acquired by any stand. The relative N gain in mixture ($N_{gainmix}/N_{tot}$) was most severely impaired by minimum site temperature ($R = 0.64$, $P = 0.010$). Nevertheless, $N_{gainmix}/N_{tot}$ was not correlated to site productivity ($P = 0.500$), suggesting that balanced grass-legume mixtures can benefit from comparable relative gains in N yield across largely differing productivity levels. We conclude that for a given amount of N fertilizer applied, higher N output can be achieved with grass-legume mixtures than with grass monocultures alone. Therefore, the use of grass-legume mixtures can substantially contribute to resource-efficient agricultural grassland systems over a wide range of grassland productivity levels, implying important savings in N fertilizers and greenhouse gas emissions.

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.

104. Classifying livestock systems for public policy guidance: the example of Colombia's livestock sector

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A growing population and the expansion of middle-class and urban diets will continue to increase the demand of livestock products worldwide. Livestock production is responsible for 50% of all agricultural greenhouse gas (GHG) emissions, while at the same time these systems provide food and livelihoods for the world's population. There is a global concern over the GHG emission potential of tropical countries, many of which house a large portion of the world's carbon sinks and who also have the potential for increased livestock production, threatening their forests and natural areas. Thus, a global dialogue has emerged that encourages the creation of public policy documents such as National Appropriate Mitigation Action Plans (NAMAs), which calculate emissions and mitigation options across economic sectors, including agriculture, and assist in proposing strategies for low-carbon development. One such example is Colombia, where the government and livestock sector are pledging to reduce the footprint in cattle pasture by 10 million hectares (a third of the current area), while doubling livestock production and decreasing GHG emissions. This talk will discuss the Sustainable Intensification Decision Support System, a tool created by the Agricultural Synergies Project of Princeton University, and its use in classifying Colombian cattle systems and calculating the production and emission potential of alternative production scenarios. We will share strategies used in classifying regional production systems at various levels of productivity, the experiences in building alternative scenarios for several regions of Colombia, and the implications that these calculations have for creating public policy guidance, including a NAMA for the livestock sector.

105. Influence of xylanase enzyme on *in vitro* methane production and rumen fermentation of tikiya (*Eleocharis dulcis*)

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Tikiya (*Eleocharis dulcis*) is one of the abundantly available buffalo feed in the water lodging saline areas in Sri Lanka. However it shows low nutritional value due to poor digestibility, high fiber content and higher enteric CH_4 production. Domestic ruminants are accountable for 25% of total anthropogenic CH_4 emission which is the second most problematic greenhouse gas contributing to the global warming and leading to a 7-15% loss of gross energy intake of ruminants. In this study, we assess the effect of exogenous fibrolitic enzyme xylanase on *in-vitro* rumen fermentation and methane emission of Tikiya. A batch culture method was used with four treatments; 10 (T1), 50 (T2), 100 (T3) and 150 (T4) µl per 500mg ground (1mm) substrates. After the pre incubation, treated samples were incubated in triplicates in a completely randomized design for 24 hours. Gas production was recorded at four-hour intervals and *in-vitro* dry matter digestibility (IVDMD) was calculated. Fermented liquid was analysed for NH_3-N, and CH_4 % was analysed using the Gas Chromatography method. Supplementation of the enzyme significantly enhanced both *in-vitro* gas production (IVGP) and IVDMD compared to the control; however no differences ($p>0.05$) within the treatments were observed. The treatment 4 showed the comparatively highest values for both IVDMD and IVGP, whilst the average gas production of substrate with and without xylanase supplementation after 24 h ranged from 54.5 to 67.66 and 48.22 ml per 0.5 g DM of substrate respectively. There was no difference ($p>0.05$) on ammonia nitrogen production between treatments and the control. Moreover xylanase supplementation significantly reduced the ratio of total gas emission: CH_4 of *E. dulcis* fermentation, but there was no difference among the treatments. Average CH_4 fraction of the total gas emission of tested substrate was 7.5%+ 0.5 at enzyme treatments, while it was 10%+ 0.57 of the control. It is concluded that supplementation with xylanase enzyme has showed a potential positive effect on enhancing the rumen fermentation of *E. dulcis*, but further investigations are necessary to find out the actual doses and effects of enzymes.

106. The effect of sunflower oil and the phenolic essential oils on methane emission in dairy cattle

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Several feed additives based on natural plants and their extracts were used to study their depressing effect on methane production in ruminants. In the same context, an experiment was conducted to test the effect of 2 feed additives: the sunflower oil, rich in polyunsaturated fatty-acids and a product rich in phenolic essential oils. For this, five Holstein cows (average weight 350kg) were used in this study; the cows were not pregnant and in the latest stage of lactation with very limited milk production. They were housed in boxes and fed individually the same ration composed of 4kg of concentrated feed and 3kg of alfalfa hay daily. Methane emission measurements were made for 2 to 3 hours after feeding termination by using facial mask connected to a methane analyzer using an open circuit system. Nitrogen gas and span gas containing 1000 PPM of methane were flushed through the system daily to calibrate the analyzer. After two weeks of adaptation to the diet, methane production was measured with no feed additives (control period). Then, 200 ml of sunflower seed oil were added to the same feeding ration for 2 weeks and a second measure of methane was performed. In third period, 44g of the product rich in phenolic essential oils were added to the feeding ration for two weeks and a third measurement of methane was performed. The daily amount of methane produced by cows was estimated to average 185 liters per day and methane was mainly emitted by eructation (89%) and the rest was eliminated through respiratory gas (11%). The effect of sunflower oil, rich in polyunsaturated fatty-acids, on methane emission was small but significant with a reduction of 8.10%. The affordability of this additive makes it a promising means to reduce emissions of enteric methane into the atmosphere. The effect of the product rich in phenolic essential oils on methane emission was significant allowing a reduction of approximately 12.75% of the production of methane. The use of phenol essential oils is an interesting test requiring further exploration.

107. Utilization of saline water by Barbarine lambs in the dry areas under climate change

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This research was aimed at determining the influence of drinking saline water after weaning on live weight change, body condition score, biological and hematological blood parameters, physiological responses, water and feed intakes, apparent digestibility, nitrogen balance and ruminal fermentation on Barbarine lambs.
Eighteen weaned lambs, at an average of 4 months old, healthy and in good condition were used in a completely randomized design. Animals were randomly assigned to two treatments consisting of water containing different levels of salt (Treatment 1 = 0.5 g of NaCl /l of water, C-sheep; Treatment 2= 10g NaCl / 1l of water, S-sheep)
The growth rate has gradually increased with the progress of the experimental period ($P<0.05$) similarly for both groups ($P>0.05$) only between the 4th and 10th weeks, S-lambs weight was slightly higher than that of C-sheep ($P<0.05$). Consequently, the body weight gain on days 30 to 90 after weaning increased by drinking saline water ($P>0.05$). However, both groups had a similar dorsal and caudal score note ($P>0.05$).
Drinking saline water increased triglyceride and cholesterol concentration 30 days after weaning as well as uric acid concentration ($P<0.05$) and decreased creatinine concentration after 90 days ($P<0.05$). However, glucose, total protein, urea and ϒ-GT concentration ($P>0.05$)., the hemoglobin concentration and the hemotocrite were slightly lower for S-lambs compared to control lambs ($P<0.05$). The rest of hematological blood parameters were not affected by drinking saline water for weaned lambs ($P>0.05$).
Weaned lambs had a higher respiratory rate during early weaning (day 0 to 30 of experimental period) than C-lambs ($P<0.05$). Moreover, no changes have been noted in rectal temperature and pulse rates under saline water stress ($P>0.05$). Besides, inclusion of 10g of salt in fresh potable water did not affect water and feed intakes compared with C-lambs ($P>0.05$).
From these data, we conclude that the short administration of salt in water to Barbarine lambs can be beneficial for increasing body weight and some of blood profiles without adverse effects on health or performance. Adaptation of the hematological blood and physiological parameters to salt permit Barbarine lambs to tolerate drinking water containing 10 g per litter of water.

108. Impact of feeding and breeding interventions towards climate resilient dairying system in India

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With a growing awareness of climate change impacts, building a climate smart livestock has become imperative. For creating climate resilient dairying in different agro-climatic regions of India, interventions in feeding and breeding using information network are being implemented through various implementing agencies, under the National Dairy Plan. So far, about 3.0 million animals have been registered and various activities are regularly recorded in this network.

Region-specific breeding policies have been formulated considering the climatic conditions and the quality of feed resources. There has been emphasis on the production of high genetic merit bulls in accordance with the breeding policy, quality semen production and efficient AI delivery network.

It is being ensured that the farmers are provided ration balancing advisory services at their doorstep through trained local resource persons using a user friendly computerized software, to ensure that their animals produce milk commensurate with their genetic potential. Field studies conducted by the National Dairy Development Board of India in different agro-climatic regions of the country have established that, on feeding a balanced ration there was an increase ($P<0.05$) in fat-corrected milk by 7.4 and 10.8%, whereas cost of milk production decreased by 15 and 10% in cows and buffaloes, respectively. Balanced feeding reduced ($P<0.05$) methane emissions (g/kg milk yield) by 17.8% in cows (n=115) and buffaloes (n=82), as measured by sulfur hexafluoride tracer technique under field conditions. Feed conversion efficiency improved by 20-30%, reduced dietary nitrogen excretion in manure from 235 to 193 g/d, indicating an improvement ($P<0.05$) in dietary protein use efficiency for milk production.

Thus, improving genetic potential, coupled with balanced feeding is playing pivotal role towards creating a climate resilient dairying system in India, which could also be applicable to other developing nations.

L3.4 Climate-smart landscapes, watersheds and territories

109. Large-scale land restoration – creating the conditions for success

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Land degradation has won renewed attention in recent years after a long period of relative neglect. The Millennium Ecosystem Assessment marked the beginning of the turnaround, putting the notion of "ecosystem services" at the center of debate on environmental policy. Then, in 2011, the Bonn Challenge set the pattern of defining specific targets for land restoration, mainly in forest landscapes. More recently, Rio+20 (the 20th anniversary of 1992 United Nations Conference on Environment and Development, held in Rio de Janeiro, Brazil) drew attention to the idea of "zero net land degradation" as one principle of the new sustainable development goals.

The reasons for heightened concern are well known – increasing land scarcity, rising demand for food, deteriorating ecosystem services – as well as the fact that land rehabilitation can contribute to increased resilience and climate change mitigation. To cite just one alarming trend, the cost of global land degradation has reached US$490 billion per year, far higher than the cost of action to reverse it.

This paper will look at how we can ensure the success of efforts to restore degraded land. It will highlight lessons around financing rehabilitation and getting the political and social buy in to make it happen. It will also explore the role of research around four key questions:

- How can we maximize returns on investment?
- What are the best practices?
- Whose livelihoods are at stake?
- How do we ensure equity and accountability?

This paper will build on results from the Global Landscape Forum on "Large-Scale Land Restoration – Creating the Conditions for Success"

110. Regional impacts of climate change and adaptation through crop systems spatial distribution: the VIGIE-MED project

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In many regions of the world, it is crucial to maintain provisioning from ecosystem services (ES) (crop, wood) and ES regulations (carbon sequestration), both strongly dependent on water availability and soil resources whilst those resources undergo strong pressures (climate change, demography inflation). Some of the key impacts of climate change on vegetation production systems occur at large scale (aquifer, watershed, forest), and the regional level (*i.e.* administrative district) is a key level for taking decisions for mitigation and adaptation. In the Vigie-Med Project, we develop indicators to characterise some of the provisioning ecosystem services linked to vegetation production (primary production, crop yield, wood production, vegetation cover, carbon sequestration, water production) and the associated risks (forest fire). In Vigie-MED, adaptation is seen through the land surface allocation between urban area and vegetation production systems, which must take into account the spatial distribution of soil and water resources and bioclimatic conditions. The understanding of land use change dynamics associated to adaptation strategies together with socioeconomic contexts (micro and macro) is an important issue of the project.
To compute relevant indicators and represent their dynamic in the future we have developed several components of a modelling framework. First, a representation of surface functioning of agricultural land has been implemented. It is based on crop models and represent at high resolution and at the regional level quantities such as the yield, biomass production, irrigation need and water flow. Similarly, a component has been developed for forest simulating vegetation growth, water consumption and mortality. Finally, a new model of land use change is under development. We have developed a small area (municipality) population projection model based on spatial regression techniques to account for interactions between municipalities and local factors having an impact on individual mobility. Transitions between cropping systems has also been investigated to assess the impact of biophysical constraints associated to climate change on agricultural systems. In this presentation we will describe the approach and the main results.

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111. Interdisciplinary approach to climate change in an intensely-managed agricultural landscape in California, USA

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The California state government commissioned a study in 2007-12 on synergies for agricultural greenhouse gas (GHG) mitigation and adaptation in a representative landscape (Yolo County), where intensive production of a diverse set of crops depends on high inputs of irrigation, fertilizer, and other fossil-fuel-based inputs. The county is vulnerable to urban expansion especially if farmer livelihoods are jeopardized by extreme events such as drought and heat waves. GCM projections, other models, and surveys were used to determine future outcomes and needs to cope with climate change. We relied heavily on use of storylines (downscaled IPCC scenarios) and stakeholder involvement in data collection. 1) Using an econometric model, wheat acreage will decline mid-century, but the climate becomes favorable for more vegetable crops. 2) Using the WEAP model, a more diverse, water-efficient set of crops combined with improved irrigation technology reduces demand below the historic mean by 2100. 3) A countywide assessment showed N_2O to be 40% of agricultural GHG emissions, mainly from N fertilizers, but cropland produces 70 times less emissions per ha than urban land. 4) An urban growth model (UPlan) indicates that channeling future development into existing urban areas, rather than into crop- or wildlands, greatly reduces the county's GHG emissions. During the period of study, a severe drought commenced in California, catapulting farmers and ranchers into the immediacy of climate change strategies. Thus the current work focusses on action-based approaches that combine biophysical research, storyline–building, and involvement with the private sector and NGOs to speed up responsiveness. Three examples include traits and irrigation management for drought in tomato, a major crop in the county (with a seed company); restoration of degraded waterways (with a conservation NGO); and a farmland conservation program for California's cap-and-trade program (with a climate action NGO).

112. Building a shared representation of the landscape as a socio-ecological system and visualizing the challenges of CSA

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Climate threats exacerbate issues of natural resource management in rural landscapes, namely water, forest and agricultural land. In order to consistently address these issues, we highlight the usefulness of a joint vision of the landscape where the actors share their knowledge on the mechanisms at work when considering the central problem that affect the landscape as well as the proposed solutions. On the basis of several case studies, we present and analyse participatory conceptual modelling as a process and a series of methods that allow building a shared understanding of the landscape as a socio-ecological system. The case study that better illustrates the diversity of suitable methods and necessary adjustments in the modelling process, is the Zapoco watershed in the Chiquitano Model Forest (Bolivia), characterized both by its natural richness and its economic poverty. In the framework of the research-action EcoAdapt project for community-based adaptation at the landscape level, we reviewed the modelling approaches which better served our purpose and ended in the articulation of tools belonging to different approaches. As a main result, we obtained graphical representations that the actors can easily understand and use to describe their context (Open Standards for the Practices of Conservation), their practices (Problem-Actors-Resources-Dynamics-Interactions) and their history (Resilience thinking). In a practical way, the models built address the complexity of the landscape and bring into focus needs for research (knowledge gaps, main uncertainties) and for action (coordination failures, unsustainable dynamics). From the perspective of companion modelling, we finally discuss the outreach of participatory conceptual modelling in the promotion of climate smart agriculture.

113. Climate-smart territory approach: for an effective address of Climate Smart Agriculture

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A Climate Smart Territory (CST) approach integrates territorial development with adaptation and mitigation actions taking into account the effects of climate variability and change, in order to achieve human welfare in a particular territory. We determined and validated a set of parameters (7 principles and 33 criteria) in three territories (Costa Rica, Colombia and Chile) of the Iberoamerican Model Forest Network (RIABM) to orient processes toward CST. The parameters determined for a CST include and complement the Climate Smart Agriculture (CSA)´s pillars (food security, adaptation and mitigation), therefore their effective implementation can address and positively impact the objectives of CSA, *i.e.*, high productivity, increased resilience and decreased greenhouse gases. CST addresses issues related to CSA, such as: conflicts that cannot be addressed at the farm scale (land use, access to water, energy security, equity); complexities that warrant a territorial approach (planning of land use, vulnerability analysis, restoration and conservation of eco-systemic services, coordinating the provision of different services [technical, business and financial]); and generation and proper use of information related to climate (exchange of information, informed decisions). The principles and criteria proposed apply exclusively to rural areas and constitute a tool for the proper orientation of climate smartness (including CSA).

114. Landscape scale assessments for strategic targeting of climate smart agriculture practices in East Africa

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Smallholder farming systems in East Africa are a complex matrix of land cover typologies, governance structures and social-economic realities. In order to better target adaptive and resilient farming systems, assessments of landscape variability at multiple spatial scales are needed. Locally appropriate climate smart agriculture (CSA) practices have the potential to overcome constraints facing smallholder farmers, but there is a need for approaches that allow for spatially explicit and contextually relevant targeting of CSA that take into account locally important biophysical constraints. We illustrate the integration of ecosystem health assessments, including key landscape metrics, and socio-economic indicators across diverse landscapes in East Africa for identification of such biophysical constraints for targeting of CSA practices. Information on current and historical land use, vegetation structure, erosion prevalence, woody cover and soil condition was collected from sites in Tanzania and Uganda. We also performed crop-modeling simulations for beans and maize using DSSAT where we applied spatially explicit and up-to-date soil information. In cases where socio-economic data were available from rapid rural appraisals or socio-economic surveys conducted by the CGIAR Research Program on Climate Change, Agriculture, and Food Security (CCAFS), these data were applied to identify opportunities and constraints to adoption of CSA practices. This analysis highlighted that soil health indicators varied across and between sites. In addition, simulated yields varied across growing seasons and soil variables were important fixed effects explaining this variation. Furthermore, our findings show that farmers with fewer soil health constraints were generally more willing to make agronomic changes than farmers in areas where land degradation was highly prevalent. This study highlights that systematic and landscape scale assessments that embrace complexity and variability could help target CSA farming systems across diverse environments.

115. The FACCE-ERA-Net Plus project "Climate smart Agriculture on Organic Soils" (CAOS)

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The FACCE-ERA-Net Plus project "Climate smart Agriculture on Organic Soils" (CAOS) focuses on farmed organic soils. They are the hotspots of vulnerability, adaptation needs and GHG emissions in temperate and boreal Europe. We propose that wet organic soils could specifically be used as risk insurance in dry periods on farm or regional level, while water and soil management could prevent yield losses due to trafficability problems in wet conditions. In the case of wet management systems, the peat is less prone to degradation, and therefore infiltration capacities are higher, and keeping water from winter to dry summer by subirrigation will be easier. Economically, alternative crops adapted to wet conditions with a stable yield quantity and quality are needed that meet consumer requirements for food, feed and bioenergy. If farmers and decision makers are to be convinced that wet management systems on organic soils are profitable and resilient under climate change, proof by on-farm experiments and historical evidence from success stories is required. Farmers and decision makers need to be involved in a bi-directional manner in every stage of the project. Overall, we aim to generate the knowledge to design climate smart agricultural systems for organic soils adapted to the diverse regional conditions of Europe. CAOS will provide and distribute evidence that active management aiming at a better control of groundwater levels, improved trafficability and alternative high productivity crops improves yield stability and quality as well as resilience to climate change while providing strong GHG mitigation and improved soil and water quality. We hypothesize that the strong potential for adaptation to increased climatic variability on farmed organic soil will facilitate mitigation of the largest GHG source from agriculture in Central and Northern Europe. At the CSA conference, we will present the project concept and first results.

116. The potential of fish as a climate smart adaptation and mitigation strategy

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We explore the role of fisheries and aquaculture in contributing to the multiple dimensions of poverty reduction and food and nutrition security for the world's poorest billion people in a climatically changing environment. We contend that if the potential of utilizing fish as a climate smart adaptation and mitigation strategy is to be fully realized, it is necessary to understand: (a) the complex multitude of direct and indirect impacts of an increase in the frequency of extreme climate events and long-term changes in climate on the sector; (b) the current contribution of fish to the livelihoods of poor communities, and (c) the environmental footprint of fisheries and aquaculture relative to other animal source foods. These highlight: (a) how short and long-term impacts of climate change exacerbate other threats to the sector, such as overfishing and natural resource degradation; (b) a current gross under-estimation of the contribution of fish to calorie intake, nutrition and income for the poor, and (c) the dietary greenhouse gas emission contribution for fish-eaters may be almost half that of meat-eaters.

We use case studies from the Pacific, South East Asia, South Asia and Sub-Saharan Africa to consider and illustrate the implications of climate change on the livelihoods of the poorest members of fish-dependent communities. The case studies also provide illustrative examples of the use of fish as a climate smart adaptation response and enable us to explore how fish may be used for mitigation. We also highlight knowledge gaps, opportunities and pathways for future research to explore the role of fish as a component within a suite of climate smart, poverty reduction and pro-poor food and nutrition security efforts needed to address gender-equitable development in a climatically changing world.

117. Water uptake in deep soil layers by tropical eucalypt plantations: consequences for water resources under climate change

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Climate models predict that the frequency, intensity and duration of drought events will increase in tropical regions. Questions such as how planted forests will adapt to future constraints on water availability have broad implications for the supply of wood at low cost that contributes to decreasing the pressure on native forests. Although water uptake by deep roots is generally considered as an efficient adaptation to drought in tropical planted forests, the role of very deep roots to supply the water requirements of trees is still poorly known. Fine roots have been observed in Eucalyptus plantation down to a depth of 16m 5 years after planting in Brazil. The contribution of water stored in deep soil layers to stand evapotranspiration has been quantified using a process-based model over 5 years after planting. Daily simulations of latent heat fluxes and soil water contents down to a depth of 10m satisfactorily matched with measurements over the study period. Our results show that deep roots play a major role in supplying tree water requirements during extended dry periods in Eucalyptus plantations. The fast exploration of deep soil layers by roots provides access to large amounts of water stored in the soil after clear cutting. The water table is no more recharged after canopy closure and the primary production is highly dependent on rainfall amounts as well as on the ability of trees to withdraw water in the water table. Water uptake by tree roots progressed towards deep soil layers during dry periods. On average 20% of tree transpiration was withdrawn below a depth of 10m during the dry seasons. The withdrawal of water in the water table, between the depths of 12 and 18m, occurred during dry periods from age 2 years onwards. Although the amounts of water withdrawn in the water table were small (~1-3% of total transpiration over the study period), this process can be of paramount importance for tree survival in tropical regions in a context of climate changes.

118. Land use practices among pastoralists as potential climate smart options for dry land ecosystems.

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Recent research has shed light on climate smart agriculture options as key adaptation strategies for farming communities. Pastoral land use practices have the potential to restore soil nutrients and sequester carbon while ensuring adaptation to climate change. However the potential of land use systems among pastoralists as climate smart agriculture option remains largely unexplored. This paper provides an integrated assessment of the land use systems by Kenyan pastoralists with a particular emphasis on adaptation and global greenhouse gases abatement opportunities. We targeted both pastoral and the emerging agro-pastoral land use systems as a way of livelihood among the ASAL communities of Kenya. Our research uses Participatory Rural appraisal methodologies to assess the local perceptions of communities on effectiveness of the land use practices contribution to adaptation and mitigation, coupled with a literature review of the potential of the land use practices abatement of greenhouse gases. We consider agro-pastoralism that is now an emerging practice among pastoral communities where communities are now farming along rivers and other wetter areas, aspects of designation of grazing areas, enclosures, Nomadic practices, privatization of grazing areas through ranches, pasture restoration practices among others. We find that although a number of practices are important as coping mechanisms to the effects of climate change, some of the land use systems could increase vulnerability of pastoralists by interfering with ecological and social integrity. We conclude the need for a comprehensive analysis to consider ecological as well as economic and social impacts of the different land use practices. Our findings are important information for decision makers and those developing climate smart options among farming communities, and may provide information on further rethinking of land use practices and thereby contribute to sustainable development.

119. Spatial models of farms territories, policy instrument and climate change: application in Chorotega (Costa Rica)

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Climate mitigation and adaptation can be tackled at the landscape scale, combining agricultural and non-agricultural components, reduced deforestation, development of agro-forestry and integrated crop-livestock systems. The spatial distribution of land use could be critical to address both the climate change issue and the income generation and distribution. Should land be spared or shared to reach climate smart goals? To answer this research question, we analyse the impact of the Costa Rican program of Recognition for Environmental Benefits (REB) on the layout of land use in farms located in the Chorotega Region (Northwestern Costa Rica) characterised by confronting environmental issues, such as the recent forest recovery process, land degradation and water scarcity. The Ministry of Agriculture has implemented the REB program since 2007. Extensive livestock is the main sub sector and area for REB use. A survey in 64 farms that participated to the REB program was carried out from March to May 2014. This survey enables to collect information related to the evolution of farms' activities and their location before and after their participation to REB. We process this information by using spatial methods (graphical modeling, "chorèmes") to identify patterns of land use distribution. Participants apply for four main types of investments: living fences, improved pasture, fodder banks, living fences or reforestation to protect water resources. They fall into three spatial models of farm land use layout. The first is characterized by a territory divided into parks for a rotating pasture. The second model is a concentration on the best land with livestock intensification and natural resources management on the remaining land. The third model corresponds to diversified farms with a spatial organization in mosaic of crops. Implications of these models for climate change adaptation (especially regarding water resources), mitigation (carbon sequestration) and food security are discussed.

120. Landscape management to develop agroforestry in Central-Africa

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In Central Africa, the degradation of tree resources exacerbates the effects of climate change (high variations of temperatures, dry air, etc.). However, attempts to limit this degradation by developing community forestry, individual forest plantations and agroforestry have often produced disappointing results. Contributing factors include a lack of land tenure security, which is required for planters and/or their descendants to benefit from the labour they invest in planting trees. Another is the vulnerability of isolated plantations, which can be destroyed by bushfires, wandering livestock, and illegal trees cutting. In semi-arid zones of northern Cameroon, as in the wetlands of D.R. Congo, research-and-development projects have combined two approaches to address these issues. The first seeks to establish Simple Management Plans (SMP) of village territories; the second to disseminate simple techniques for the collective management of natural forests and for setting up individual agroforestry plots using plantation or Assisted Natural Regeneration (ANR).The evaluation of these projects, based on surveys of villagers and forest inventories, shows that the combination of these two approaches may indeed enable villagers to slow the degradation of their natural resources and engage in a dynamic reconstruction of the tree component of their territories. However, the success of these combined approaches is contingent on several conditions. First, villagers must collectively see resource degradation as a danger and their restoration as an opportunity for a better future. The support of traditional authorities and administration also is required. Finally, to ensure that rebuilt agro-systems are well adapted to the current and future needs of populations under evolving environmental conditions, the support of research and development is often necessary from the earliest stages. This was the case for the enrichment of *Faidherbia albida* parklands in northern Cameroon and for improving systems of shifting cultivation by planting trees and implementing ANR in DR Congo

121. Governance for climate smart landscapes: a case from Makueni County, Kenya

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It has been suggested that "climate smartness" of agriculture can best be assessed not at plot or farm level but at landscape level. Maladaptive agricultural practices for instance often export environmental costs from farms to wider landscapes. Land use and tenure patterns, upstream-downstream interactions within agricultural watersheds, and other relationships that play out at landscape level are among the chief obstacles to achieving climate smart agriculture. We understand these obstacles as being primarily challenges of governance.

The aim of this study was the assessment and diagnosis of governance at the level of a particular landscape within Makueni County in eastern Kenya. We used a mixed methods approach that included semi-structured interviews with key informants, focus group discussions with a variety of demographic and other stakeholders groups, multi-stakeholder workshops and participatory scoring techniques. Purposive sampling was used to ensure that a wide variety of perspectives were included. Audio recordings of interviews and focus groups were transcribed and analysed with the Nvivo 10 software using an analytical framework designed for investigation of institutional and governance dimensions of climate change adaptation.

Our assessment found that within the emergent governance system that pertains to this landscape, the level of accountability is reasonable at local levels but weaker at higher levels where some other aspects of governance such as the ability to generate financial and political resources are stronger. The respective governance strengths at these different levels are potentially complementary, but appropriate institutional linkages which could help to achieve this complementarity are very weak. Recent reforms that are helping to build capacity and establish institutional linkages among key actors have recently started to improve governance, but generally the governance system has little capability for addressing adaptation challenges in an effective and holistic way.

122. A landscape approach to co-designing climate change adaptation and mitigation strategies with farming communities

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It is commonly accepted that climate smart agriculture (CSA) is much more than a new variety or cropping practice such as those that made the Green Revolution possible in the 1960s. CSA is about managing trade-offs between (i) intensification (*i.e.* sustainable productivity increase), (ii) mitigation and (iii) adaptation to climate change. The synergies between these three pillars of CSA have been explored through a territorial approach to agroecology that combines participatory land use planning and sustainable intensification of agriculture. The approach developed by the Eco-Friendly Intensification and Climate resilient Agricultural Systems (EFICAS) Project is based on an in-depth understanding of the patterns and drivers of land use changes in the northern uplands of Laos. It was shown for example that labor productivity gains from agricultural innovations (*e.g.* mechanization, use of chemical inputs) have systematically been reinvested by farmers into an expansion of cropping areas which is detrimental to the forest covers. It is therefore essential to first engage local communities in collectively planning their land use by defining an acceptable combination of land sparing between sustainably managed forested and agricultural areas, and land sharing featuring complex agroforestry systems integrated with livestock. Then, multiple stakeholder groups (including extension agents, development partners, policy makers and private sector) are involved in negotiating and supervising landscape level intensification patterns that synergize mitigation (*e.g.* carbon sequestration, soil conservation) and adaptation (*e.g.* resilience enhancement) to climate change. Last, multiple scenarios and implementation pathways based on agroecology practices are explored collectively through a theory of change process.

123. Adapting landscape mosaics within Mediterranean rainfed agrosystems for managing crop production, water & soil resources

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Mediterranean Rainfed Agrosystems (MRAs) provide numerous agri-environmental services. In the meantime, expected evolutions for climate and anthropogenic forcing threaten the MRA capabilities to provide these services over the long run. It is therefore necessary to adapt agricultural activities and resource use to the forthcoming pressures. A promising management strategy to be explored is the modulation of landscape mosaics to balance between various agri-environmental services (*e.g.* biomass production, downstream water delivery or soil preservation). Landscape mosaics can be seen as (i) networks of natural and anthropogenic elements, (ii) structures that impact landscape fluxes and resulting functions, and (iii) a possible lever for managing agricultural catchments. Further, any balance on various agri-environmental services should result from evolution scenarios that are acceptable by all stakeholders. For this purpose, we propose to design and test a new integrated assessment and modeling approach that (i) addresses landscape mosaics evolution and related processes from the agricultural field to the resource governance catchment, and (ii) includes stakeholder innovations and action means into prospective scenarios for landscape evolutions. This requires tackling methodological challenges in relation to i) the design of spatially explicit landscape evolution scenarios, ii) the coupling of biophysical processes related to agricultural catchment hydrology, iii) the quantification of economic impacts of landscape evolutions and resulting services, and iv) the digital mapping of landscape properties. The proposed approach is tested within three catchments located in Tunisia, France, and Morocco. These agrosystems are economically important and they are threatened by global change.

Further, the resulting catchment set permits to consider very different situations for landscape evolutions. Significant advances are expected by reasoning spatial organizations of land uses and cropping systems. Identifying new action levers should result in innovative recommendations from a spatial organization perspective, but may also lead to revise former recommendations at the finer and coarser spatial scales, for the benefit of stakeholders.

124. Watershed and biodiversity restoration in the Western highlands of Cameroon under climate change

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Cameroon as many other countries of sub-Saharan Africa faces many challenges; a rapidly growing population (from 1.93 to 2.19 % between 2005 and 2009), expanding urban areas, unsustainable agricultural and forest exploitation practices that lead to land degradation and potentially climate change.

In pre-colonial times villages lived as collective entities under powerful traditional chiefdoms with strong family ties and shared all resources in common. With the coming of independence and the shift in authority from traditional to local government, the ties that bound families and communities together gradually waned giving rise to the destruction of 'sacred forests' which were a common property resource. Successions of offspring lead to partition of land, resulting in fragmentation of these common pool resources making it difficult to manage the latter on a sustainable basis. Lack of appropriate planning or apathy on the part of the government in the wake of unfolding situations is largely to blame for the present problems. Even where the administration has recognized the problems, it has failed to concretely address them in a pragmatic manner due to lack of political will coupled with economic limitations. To – in

The key problems have been catalogued as soil erosion, siltation, flooding, depletion of soil fertility, diminished water yields, lowering of water tables and landslides affecting the common-pool resources. Additionally, these problems have been considered as arising from the use of poor and inadequate traditional shifting cultivation methods, excessive deforestation especially in water catchments areas, cultivation on fragile (steep) hill-slopes, setting of bush fires, overgrazing by cattle, and building of settlements. The potential negative impacts of climate change would add other constraints to agricultural production if nothing is done. In effect, countries need to respond to the challenges posed by climate change.

This paper was conceived to propose solutions for the management of watersheds in order to serve the interests of the commons as the resources within the watersheds – which are collectively used by the entire community – are rapidly degrading. The proposed activities to be carried out include: soil and water conservation practices, agro-forestry operations, in-situ and ex-situ conservation of plant species (fruit trees, medicinal plants, spices, forestry tree species, etc.) and ultimately monitoring of sediment pollution and water flow with the establishment of the 'climax vegetation'. This paper will cover those activities and show how they will contribute to the study of the commons and to the preservation of common pool resources in order to mitigate effects of climate change especially in the Western regions of Cameroon.

L3.5 Investment opportunities and funding instruments

125. Livestock farmers' investment toward climate-smart production: impact of an incentive program in Chorotega, Costa Rica

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Aside from the well-known payment for environmental services program for forest conservation, Costa Rica engaged in an agro-environmental program as an incentive to small and medium farmers to implement sustainable farming systems in 2007. This program expressly aims at mitigation and adaptation to climate change and targets livestock farming as a main source of greenhouse gas emissions. Conditioned on investing in some assets identified as leading to both improved natural resource management and enhanced productivity, a cash reward called "Recognition for Environmental Benefits" (REB) is granted to voluntary farmers and accounts for 20-30% of the investment cost. The effectiveness of such an economic policy instrument to enhance farmers' adoption of sustainable practices relies on the extent of additional versus windfall effect. We used treatment effects methods to estimate the additional impact of REB program on participants' investment between 2006 and 2012. Based on a sample of 63 past and future participants in the Northwestern region, we found that REB participation had significantly increased the adoption of some types of eligible assets. Moreover, we identified an indirect effect on farmland uses and an increment in stocking density, caused by REB participation. Finally, we attributed a carbon sequestration index to each farm in both years, according to its land uses and considering the literature. Mitigation, adaptation and food security have been discussed, and we concluded that REB program has supported the implementation of climate-smart solutions for livestock production, in one of the poorest and most drought-prone regions in the country.

126. 25 million African farming families by 2025: science-development partnerships for scaling climate-smart agriculture

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Climate-smart agriculture (CSA) has rapidly been integrated into the development lexicon and recently became the flagship for the African Union New Partnership for Africa's Economic Development's (AU-NEPAD) 'Vision 25 x 25' that aims to reach 25 million farm households practicing CSA by 2025. Here we lay out the technical and research framework for supporting Vision 25 x 25 that has been co-developed by scientific and political actors at AU-NEPAD and the CGIAR Research Program on Climate Change, Agriculture, and Food Security (CCAFS). The framework operates through two interrelated and mutually reinforcing workstreams. The first workstream lays the ground work to refine CSA's definition for the Africa-context, identifies implementation targets for countries and sub-national governance units, and develops indicators to track and assess CSA adoption on-the-ground. The second workstream supports CSA implementation through baseline assessments that guide policy, problem definition for programmatic development, and guidelines for implementing specific CSA practices. A CSA toolbox is being developed to prioritize technical CSA options in the context of climate risks and vulnerability, which combine to create portfolios of CSA packages specific to national and community level planning processes. These workstreams are complemented by the development of cohesive on-going research and development on knowledge management, CSA technology development, and analytics. This is all being conducted in the context of cross-cutting and underlying factors of: gender and other vulnerable communities; land policy tenure, and administration; markets and value chains; environmental and natural resources; and rural area based livelihoods. This framework is aimed at integrating with the African development processes of AU-NEPAD, the African Regional Economic Communities (*e.g.* COMESA, ECOWAS), the African CSA Alliances and the Africa Union member states' National Agricultural Investment Plans (NAIPs).

127. Microfinance and Climate Smart Agriculture: integrated farming system and social business

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Philippines as a tropical country is constantly affected by natural calamities such as typhoons, La Niña and El Niño phenomena, and is the subject of the CORDAID program on Microfinance and Climate Smart Agriculture: Integrated Farming System and Social Business. This program aims to address the common problems of the country's 55% rural population dependent on agriculture to gain effective access to agriculture technologies by converting them to become full-time farmers, and address the issues of price stability and food security.
The majority of the farmers live on meager income due to poor access to capital, confronted with bridging the income gap from planting to harvest. Farmers continue to be marginalized and poor. Technology is available but useless if the farmers themselves are unable to achieve sustainable income. By redesigning the access to sustained capital, social business and technology through microfinance institutions, the farmers were able to achieve sustainable income through integrated farming systems, laddered farming methods, achieved price stability through social business and sustained food security for themselves and their communities.
The Pilot testing of the program enabled the farmers to access production fund 5 times the usual loans received (from USD600 to USD3,000 per hectare per cropping), increased labor participation rate, increased use of various agriculture technologies and climate change resilient crops and practices, significantly improved income as well as improving their ability to cope up with the regular natural calamities as evidenced in the recent strong typhoon "Haiyan" last November 2013.
From 2015, CORDAID and its partner Microfinance Institutions will roll out the program to saturate at least 250,000 farmers within 5 years, hoping to strengthen the marginalized agriculture sector through better financial intermediation schemes, use of effective technologies, implementation of a sustainable agriculture that will achieve a climate smart agriculture program.

128. The CLIFF Network: breaking knowledge barriers for climate change mitigation research in developing countries

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A lack of intellectual human capacity, financial resources and analytical infrastructures are some of the major barriers to conducting climate change mitigation research in developing countries. To address the challenge of limited intellectual human capacity, the Climate Food and Farming (CLIFF) Network was formed in 2011 as a collaborative initiative between the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), University of Copenhagen and Aarhus University. The specific objectives of the CLIFF network are 1) to enhance the quality and quantity of scientists addressing climate change mitigation and food security challenges in developing countries, and 2) to support innovative postgraduate research addressing these challenges. To achieve these objectives, the CLIFF Network annually selects at least eight to ten students conducting climate change mitigation research in developing countries, through a competitive process. Selected grant recipients then participate in a three-day workshop to receive training on various issues related to the underlying processes for greenhouse gas production and emission, low-cost methods for monitoring greenhouse gas emissions, model building and the use of greenhouse gas calculators. The Network then provides financial resources to support the research of selected students and facilitate South-South knowledge exchange. During the past three years the Network has supported a total of 27 students from across the world to work on a diverse range of topics related to climate change mitigation. Presently, as a result of the CLIFF grants, at least 15 scientific peer-reviewed articles on climate change mitigation have been published in journals and conference proceedings. More importantly, several previous grant recipients are now contributing toward facilitating change by breaking knowledge barriers on climate change mitigation in their various institutions and countries.

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129. Adaptation strategies for floodplain agriculture in Amazonia

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Seasonally inundated floodplains in the Amazon Basin benefit from annual deposition of nutrient rich sediment from the Andes. These open tracts of land offer much potential for low input agriculture but are prone to flood risk. Climate changes are predicted to affect the extent, duration and timing of flooding in the northwestern Amazon Basin. Data were collected on crop loss, coping strategies, and risk preference though household surveys (n=83) and focus group discussions (n=8) in four riverine communities near Iquitos, Peru along the Amazon River. Key informant interviews and land elevation surveys provide the policy context and the probability of flood related crop loss. The research identifies farmers' receptiveness to agricultural flood insurance, flood information services, and flood resistant varieties through willingness-to-pay methodologies. We examine how market integration and risk and ambiguity aversion influence adaptation preference. Findings suggest that index-based weather insurance through public-private-partnerships and appropriate information provision may assist farmers to make fuller use of the Amazon floodplain and enable risk reduction practices.

130. Afforestation and the unemployment nexus in the West African forest reserves localities: case study of Nigeria

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In the light of the constraints to mitigating climate change especially across the tropics, the current study assesses afforestation and the unemployment limitation in the Nigerian forest Reserve areas. Specifically, the study examined socio-economic attributes of rural dwellers, the nature of forest reserve activities, unemployment and other constraints leading to afforestation and profiled the characteristics of low wage jobs vis-à-vis afforestation drivers in these areas. The study involved a survey of one hundred and sixty households within the forest reserve areas of Kwara state, Nigeria.
Analysis was made via Ordinary Least Square OLS regression, likert scale and the two-stage heckman probit analyses. The result shows that majority of the forest household heads were engaged in diverse income generating activities including illicit ones like fire wood gathering, forest reserves tree falling for charcoal production and lumbering activities. Their perception regarding the inimical influence of their illicit deforestation activities was found to be however blurred by their need to meet their household basic needs via the incomes they obtain from their activities. Factors found to determine their deforestation activities include poverty; this was followed by their poor orientation towards deforestation and climate change dangers, poor commitment on the part of forest reserve authorities and non-provision of forest materials substitutes for fire-woods and other wood demanding activities. In conclusion, it is implied from the study that households in the forest reserve areas of Nigeria are under what could be termed as 'forced deforestation activities' because of the urgent need to meet up with their basic needs. In this vein, the study recommends the development of poverty alleviation and alternative income generating activities in the forest reserve areas. There is an urgent need to overhaul the forest reserve governance system and to undertake researches aimed at developing new materials that could substitute wood used for fire-wood and other wood demanding activities.