MODELLING APPROACHES FOR CLIMATE RISK AND ADAPTATION IN THE CONTEXT OF SUSTAINABLE INTENSIFICATION

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Workshop Report

CGIAR | AICCRA
Accelerating Impacts of CGIAR Climate Research for Africa

Acknowledgements

The authors owe immense gratitude to Volkswagen Foundation and the World Bank through the IDA (International Development Association) supporting the AICCRA (Accelerating Impacts of CGIAR Climate Research for Africa) project.

The authors would like to thank several individuals :

- Dr Dilys MacCarthy (University of Ghana), Dr Marc Crobeel (IITA/CIRAD) and Dr Anthony Whitbread (ILRI) for their excellent facilitation, collaboration and contribution to the activity reported here.
- Dr Abdramane Wane (ILRI) , Dr David Berre (CIRAD), Dr Joshua Aboah (ILRI), Dr Babacar Faye (USSEIN) and Dr Florent Noulèkoun (University of Korea) for their contribution to knowledge transfer.

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List of abbreviations

AICCRA	Accelerating Impacts of CGIAR Climate Research for Africa
AIMS	African Institute for Mathematical Sciences
APSIM	Agricultural Production Systems sIMulator
CBA	Cost Benefit Analysis
CERAAS	Centre d'Etude Régional pour l'Amélioration de l'Adaptation à la sécheresse
CIRAD	Centre de Coopération Internationale en Recherche Agronomique
CMRA	Modelling approaches for climate risk and climate change adaptations in the context of sustainable intensification in semi-arid West Africa
CNRA	Centre National de Recherche Agronmique
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock research Institute
IPCC	Intergovernmental Panel on Climate Change
ISRA	Institut Sénégalais de Recherche Agricole
MSP	Multi-Stakeholder Process
TPE	Target Population Environments
VCA	Value chain analysis
WTP	Willing To Pay
ZALF	Leibniz Centre for Agricultural Landscape Research

I. Introduction

From September 11th to 17th 2022, was held at the Centre d'étude régional pour l'amélioration de l'adaptation à la sécheresse (CERAAS), Thiès Escale, Senegal, an international summer school (summer school CMRA-2022) organized by the Leibniz Centre for Agricultural Landscape Research (ZALF) in collaboration with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the International Livestock research Institute (ILRI).

With the financial and technical supports of Volkswagen Foundation and AICCRA project, this summer school equiped the West Africa's next-generation agricultural researchers and policymakers to use modeling tools to accelerate decision-making in addressing climate risks and sustainable intensification. A total of 32 participants from across European, Asian and African institutions that have different background were convened. The summer school was designed to provide Master, doctoral and postdoc scholars with a broad overview of the system's analysis, best practices in model application climate change impact assessments, as well as emerging applications and challenges for crop modeling to support sustainable intensification of smallholder farming systems. The participants were equipped with the knowledge and skills to use crop models in the design and evaluation of resilient and productive cropping systems.

The course was offered in English, partially translated in French and consisted of lectures by 12 international experts, practical work, group work, field visit and discussions.

II. Participants' expectations

The introduction session was made with learners expectations (Figure 1) from the course and list the points or aspects that should be emphasized most by the lecturers during the course. The three main expectations of the participants were:

- To enhance their ability to use the Agricultural Production Systems sIMulator (APSIM) which is a dynamic crop model developed to simulate the biophysical processes in agricultural systems
- To improve their understanding of the West African cropping systems and simulation.
- To build a network of crop modelers in West Africa that gathers participants and lecturers from the summer school and other crop model users of the region.

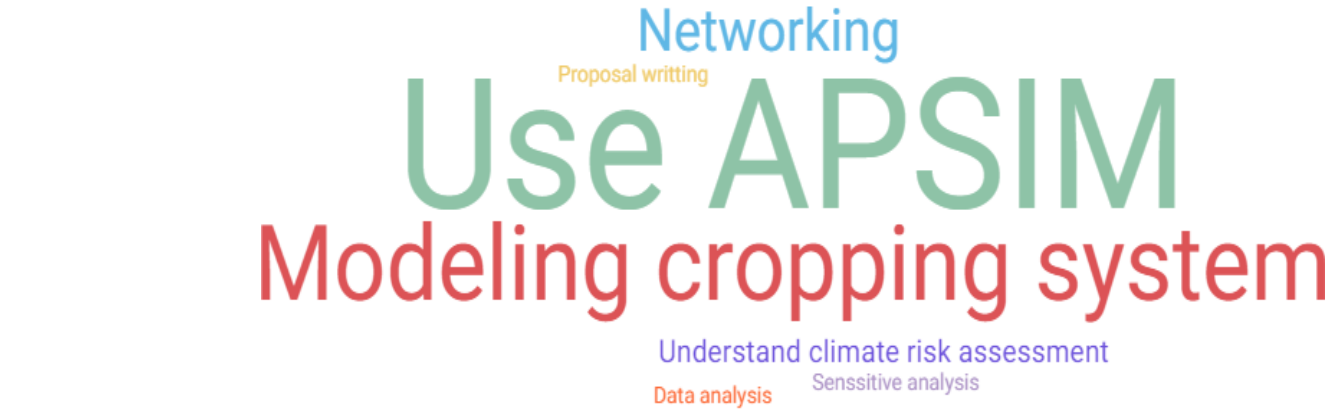


Figure 1. Participant expectations

Photo 1: Group photo of the summer school

III. Crop modeling approaches: limitations and alternatives in West Africa (discussion)

On the third day, group discussions were led by Dr. Marc Corbeels,(IITA/CIRAD) which highlighted the prospects and challenges of crop modeling in the West African context. Different constraints were mentioned by the participants:

3.1 Data accessibility and credibility

Data necessary to run crop simulation models are often not available in the existing databases because they are frequently not collected by the existing research programs. A solution proposed by the participants to overcome this challenge was to involve crop model users in the implementation of project activities and the data collection process. The second problem mentioned by the participants was the data credibility. Existing datasets were more often collected using the "pen-and-paper" approach followed by a manual data entry. This approach is less efficient and prone to errors. Moreso, appropriate data storage and management systems are more often missing, particularly in the national research centers. As a consequence, available datasets are either incomplete or unusable for modeling purposes.

Several solutions have been proposed to address these issues:

- Search for funding for data collection using adequate equipment that are more efficient and easy to use
- Promote the transdisciplinary research through the involvement of all disciplines in the data collection process within a research program
- Create data storage and management options for the national research centers

3.2 Model use, improvement and development

The limited skilled human resource base that can utilise crop models is another challenge faced in West Africa. This limited number of skilled human resources are mainly model users, who are limited to the use/application of the existing crop or system models, and are not trained to develop new models or capabilities. To resolve this issue, different solutions have been proposed and are listed below:

- Build the capacity of African scientists in developing and or improving the existing crop and system models

- Include the crop and system modeling and model improvement programs in the curricula of graduate students in the universities in order to build the capacity of young generation in the use, improvement and development of models

- Involve the mathematics and physics students from schools such as the African Institute for Mathematical Sciences (AIMS) in the ongoing modeling projects in the region

- Find more attractive approaches to communicate about the need to use crop and system models in order to captivate more usersInform policymakers about the importance of modeling by involving all stakeholders (policy makers at decision level, extension service, etc) in the implementation of the model-based researches in order to address the concerns and issues of farmers in West Africa

- Modify existing crop models by including some leading food crops like cassava, yam, and taro, that are important staple food crops for smallholder famers of West Africa

IV. Project work: which model, data, and analysis?

The objective of the group work was to develop a research proposal on a topic related to climate risk, food security, and sustainability with a strong crop modeling component. The participants were divided into small groups of 4 to 5 people according to their mutual interest topic and the working language (French or English). To facilitate the quick formation of the groups, 4 topics were pre-selected:
1) Breeding for climate resilience, 2) Co-designing climate resilient and sustainable cropping systems, 4) Affordable insurance products 5) Policy support for the Intergovernmental Panel on Climate Change (IPCC) climate negotiation processes. Thus the five (5) groups were set among which , three (3) were English-speaking groups and two (2) were French-speaking groups. The group work consisted, according to the chosen topic, of defining the research subject, the methodology adopted, the expected results, and the impact of the study. After the group work sessions (3 sessions in total), the projects were shared with the trainers responsible of the evaluation.

After the evaluation, a presentation of the different projects was made followed by the different remarks and contributions of the evaluators.
A summary of the different research groups is described below:

4.1. Group 1: Crop Breeding for climate resilience

Project title:

"Innovations to support sovereign and sustainable food systems in the Sahel (Food3S)"

Research objectives:

This project intends to characterize pearl millet ideotype maps adapted to the Sahelo-Saharan climate using a crop model. Specifically, the project plans:

- To best incorporate climate uncertainty into the G × E interaction analysis models, to have a better representation of the pearl millet TPEs (Target population Environments).
- Identify for each TPE the best ideotypes to mitigate the impact of climate change.

Methodology:

- Evaluate the performance of existing pearl millet varieties for different climate change scenarios
- Varietal design using a crop model
- APSIM-MARKSIM coupling

Study impact:

1. More precise identification of the constraints that govern the interactions between genotypes and environments (G×E). Specifically, we will identify the environmental constraints present in each TPE (Target Population Environment);
2. Identification of the combinations of agro-morphological/genetic traits that underline better production for each TPE for a more accurate profile of breeding products.
3. Elaboration of planning of the ideotypes to be developed by the breeders according to the different scenarios of climate change.
4. The introduction of varieties adapted to climate change can minimize the negative effects of climate and provide environmental and socio-economic benefits. It is therefore essential to improve the understanding and modeling of climate change factors on agricultural production systems.

Group members:

Oumar Diack, Diariétou Sambakhé, Mohamed Doumbia, Modou Mbaye

4.2. Group 2: Co-designing climate resilient and sustainable cropping systems (a)

Project title:

"Enhancing small-holder farmers' resilience towards climate change and risks through innovative cropping systems in the Sahel, West Africa (EFRI-Sahel)"

Research objectives:

This project intends to improve the livelihoods of rural dwellers through innovative, sustainable, and market-oriented cropping systems that will enhance their resilience toward climate change and risks. Specifically, the project aims to:

1. Understand the current scenarios of cropping systems to inform innovative systems through the multi-stakeholders process (MSP).
2. Co-develop tools and technologies with and for the farmers and stakeholders to improve productivity and resilience to climate change.
3. Identify and create avenues to reduce climate risks and encourage rural development through value

addition, adopting gender-responsive approaches

Methodology

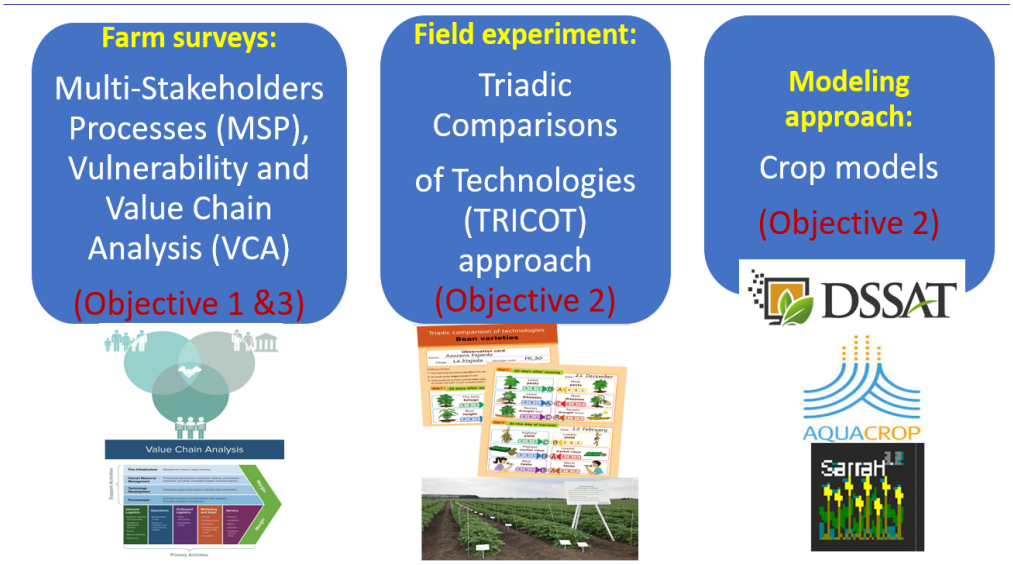


Figure 2: steps in the methodological approaches for co-designing climate resilient and sustainable cropping system

- Understanding the current scenarios of the cropping systems by employing the multi-stakeholders processes (MSP) to a) Initiate the process, b) Build sustainable collaboration, and c) Manage collaboration
- On-farm trials of crop varieties and sustainable cropping practices using 'tricot' experiment design
- Identification and creation of avenues to reduce climate risks: a) participatory vulnerability and value chain analysis (VCA), b) identify possible viable business options, to provide targeted technologies and solutions, c) both qualitative and quantitative approaches of VCA will be used in this project and Capacity strengthening of stakeholders and d) intentional training, skills, and knowledge acquisition programs.
- Project structure**:**

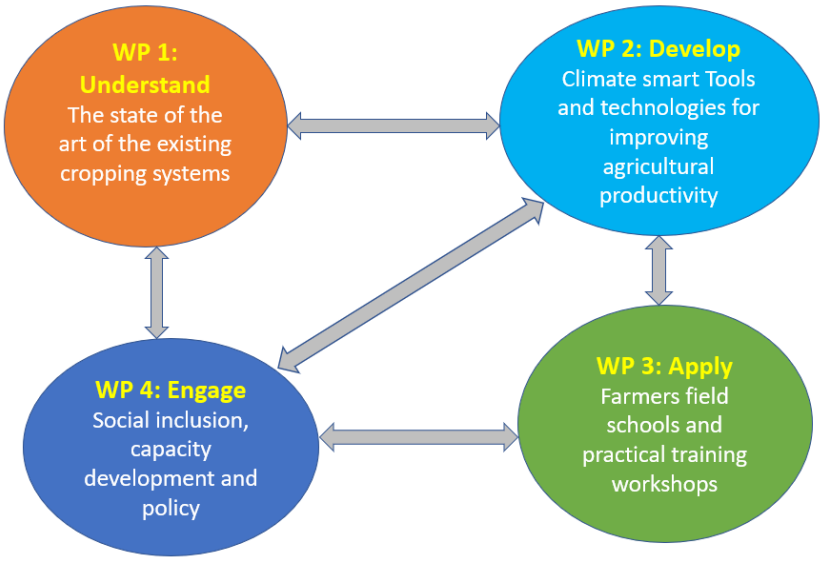


Figure 3: Work packages for climate resilient and sustainable cropping system project

Foreseen impacts:

1. 3,000 farmers as direct beneficiaries, with 60 % of them being women and youth
2. Capacity building of NGO and government agents (100), students (6), and researchers
3. Average yield increase through reduction of yield gap
4. Strengthen collaboration between farmers' stakeholders and researchers
5. The present project will improve farmers' livelihoods and their resilience to climate change while strengthening their collaboration with researchers;
6. By placing the farmers at the heart of the method, this project opens a window for future fruitful collaboration with the farmers.

Group members:

Agossou Gadedjisso-Tossou, Adiele Joy Geraldine, Umutoni Clarisse, Bagagnan Abdoul-Rasmane, Sanogo Karamoko, Tougma Ines Astrid

4.3. Group 3: Co-designing climate resilient and sustainable cropping systems (b)

Project title:

"Sustainable intensification of mixed cropping systems"

Research objectives:

This project plans to improve the productivity per unit area of land and livelihood of smallholder farmers, while conserving the natural resource-based (especially for women and children).

Methodology:

- Description of the project background

Mixed cropping systems:

Integrates genetic, ecological, and socio-economic innovations & information

Increases productivity per unit land, labor, capital, etc.

Ensures efficient, prudent use of inputs

Conserves or enhances natural resources

Increases resilience, equity & reduces risks

Figure 3: Representation of the system complexicity for sustainable intensification

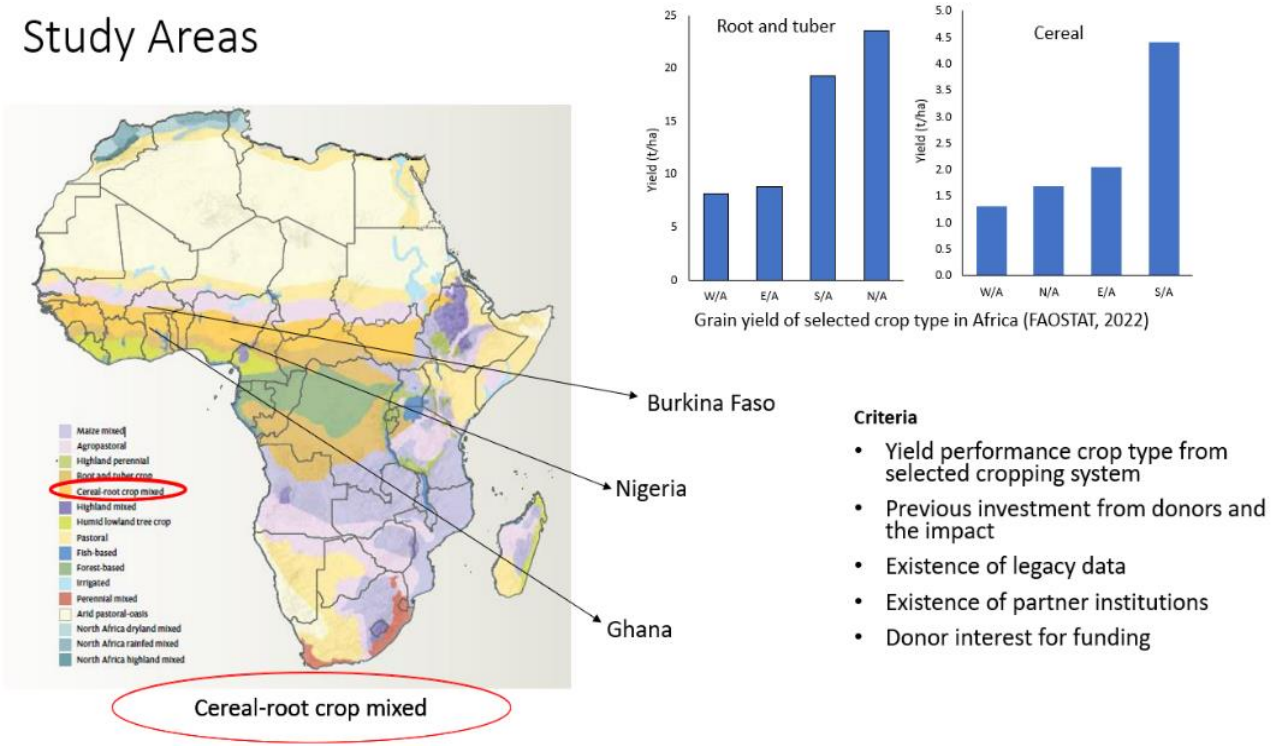
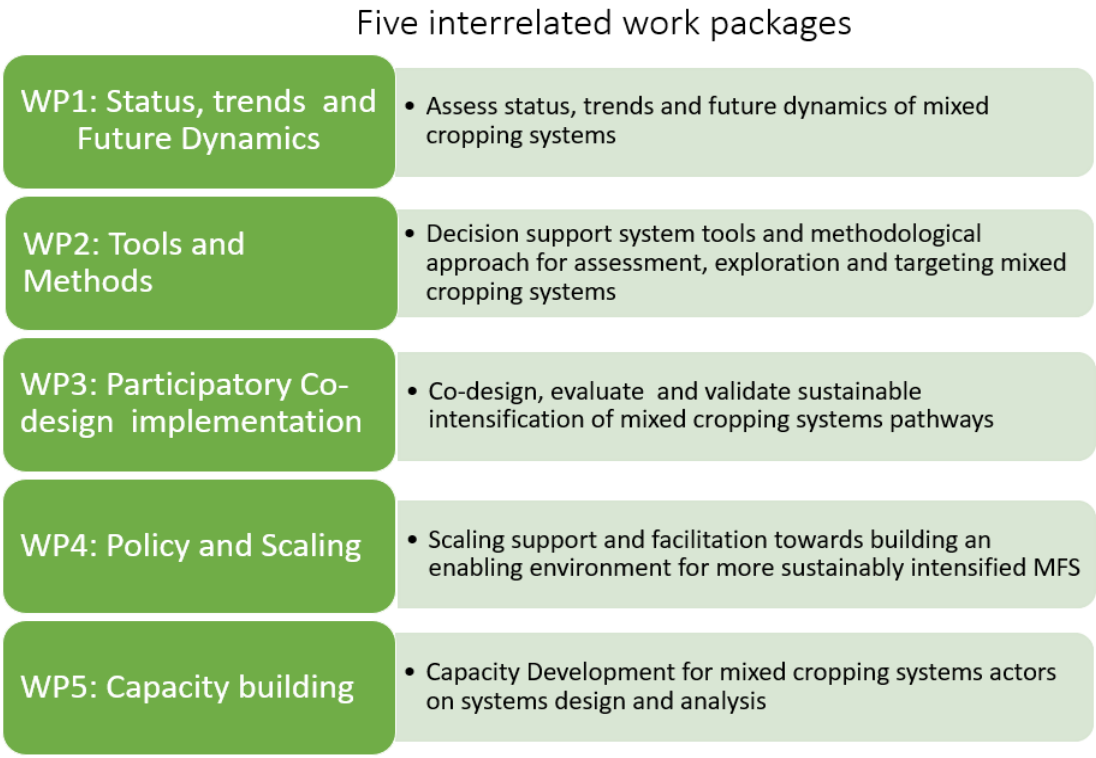
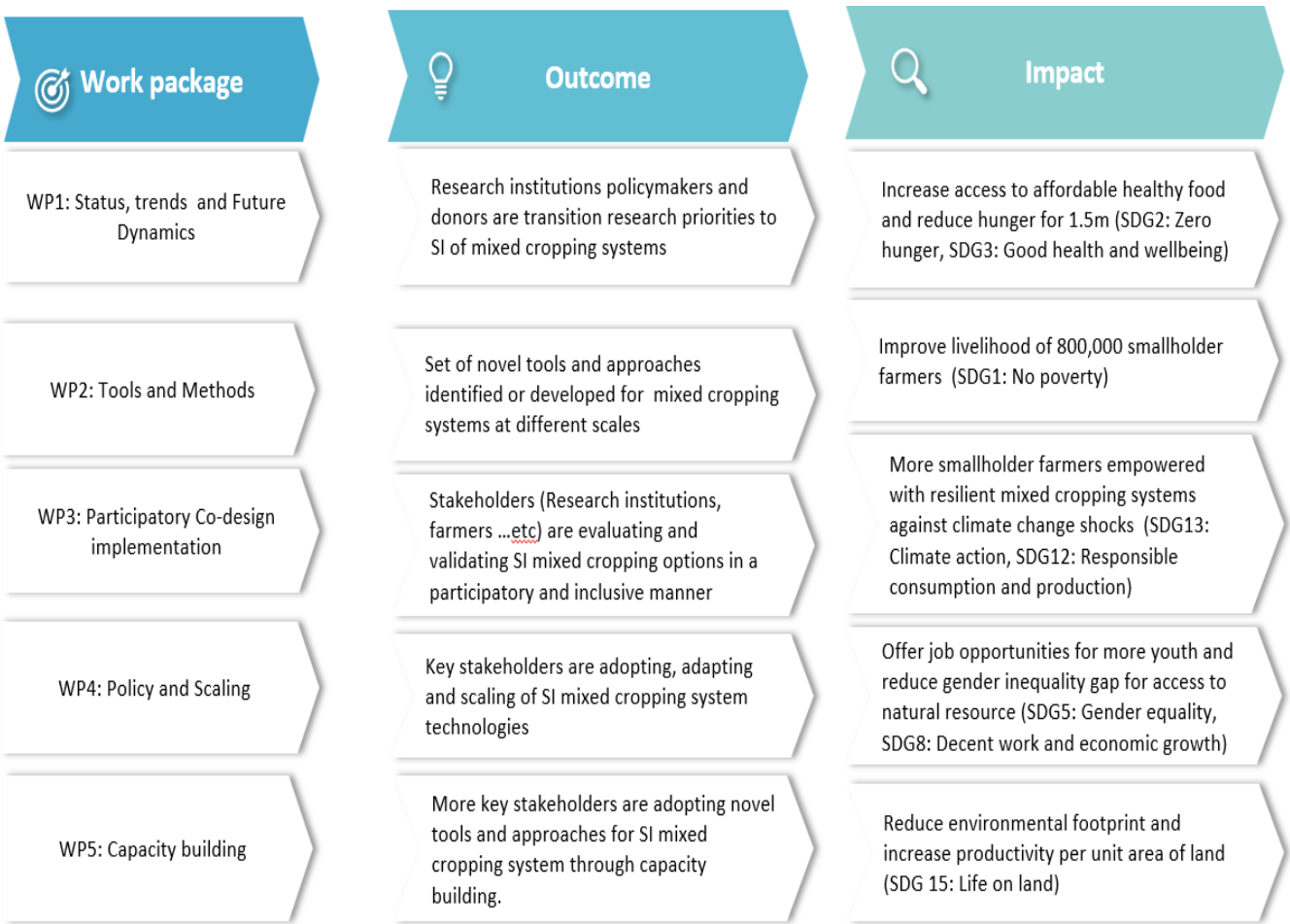


Figure 4: Study areas

- Project structure:



Impact pathway:



Group members: Abdul Rahman Nurudeen, Isaac Danso, Jenneh Fatima Bebeley, Dotun Arije, Inoussa Zagre , Yelogrnisse F. U. Agbohessou, Diane Cooke.

4.4. Group 4: Affordable insurance products

Project title:

"The demand and the suitability of crop insurance in Senegal and Cote d'Ivoire: A modelling approach"

Research objective:

This project aims to introduce modelling approaches to study the imbalance between supply and demand of crop insurance.

Methodology:

- Area: Semi-arid and sub-humid zones with a specific focus on Senegal and Cote d'Ivoire.
- The targeted group is smallholder cocoa and peanut farmers

The integrated modelling framework:

- Policy analysis approaches
- Probability of yield failure,
- Farmers' willingness to pay,
- Cost-benefit analysis both for farmers and insurance companies, and
- Barriers analysis to create enabling environment

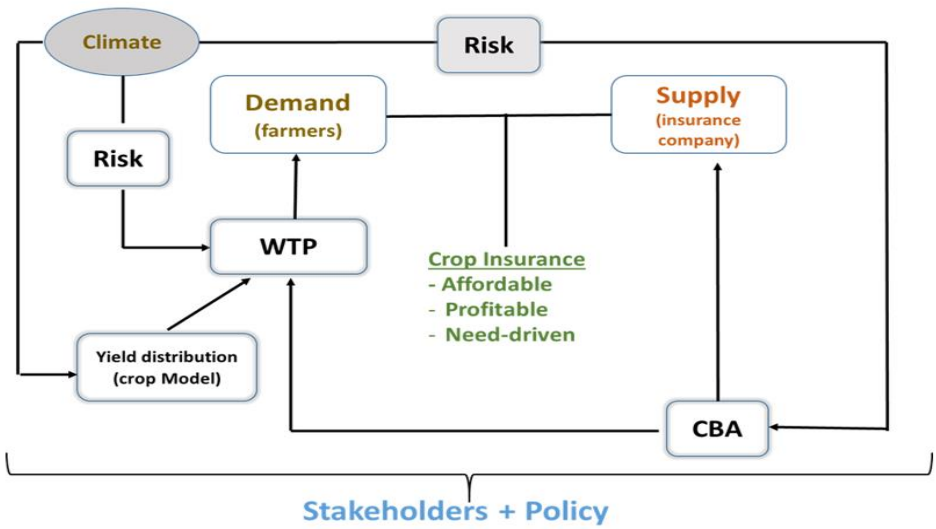


Figure 5: conceptual framework for modelling

Project structure :

Components	WP1: Crop Modelling	WP2: Economic Modelling	WP3: Climate Modelling	WP4: Policy and Stakeholder analysis
Data	- National and subnational yield production data 30yrs historical data - Soil data - Weather data - Crop type and Management	- Socioeconomic data - Cost of production - Income - Cost of Insurance - Farm endowment	Future projection: baseline 1991-2020 and future 2030-2050	- Stakeholder map - Agricultural policies - Regulatory framework of the insurance.
Models/ Methods	APSIM, SIMPLACE, WANUSCLAS	Agent base model, linear programming	GCM, Ensemble	Participatory approach
Scenarios	SSP3-7.0, SSP5-8.5	SSP3-7.0, SSP5-8.5	SSP3-7.0, SSP5-8.5	Policy Incentives
Analysis	Probability of crop yield failure risk	- Farmers willingness to pay - cost-benefit analysis of insurance (perspective of farmers and insurance company)	Future projection and trend analysis.	Policy review

Expected results:

- To reduce the current cost of insurance by 10% in the year 2050
- To increase the insurance coverage of farmers in the region by 20%

Group members:

Opeyemi Obafemi, Koko Namo Lawson-Zankli, Taiwo Ewulo, and Elida Kossi Daku

4.5. Group 5: Policy support for the Intergovernmental Panel on Climate Change (IPCC) climate negotiation processes

Project title: "Trend of Soil Organic Carbon, evidence of climate change for advocacy to the IPCC negotiations"

Research objectives: This project plans to provide scientific evidence justifying the occurrence/impacts/effects of CC in SSA for advocacy during COPs/ICMs. More specifically,

- To assess impacts and vulnerabilities on cereal (millet and rice) and legume (groundnut) cropping systems
- To propose mitigation and adaptation options
- To develop a policy brief for negotiators

Methodology:

- Modeling: using DSSAT-CENTURY/CRAFT
- Field data collection: Selection and monitoring of farmers' plots of pearl millet, groundnut, and rice in Niger, Senegal, and Togo, collection of soil and yield data, and collection of climate data at plot level
- Calibration, validation, and projection: the model will be calibrated using the part of the field data and validated with the other data, test the sensitivity of the model to SOC variation and adjust (if necessary), collect current regional climate data (observed data), SSP projection climate data (SSP 2.6, 4.5, 7.0 and 8.5), AFSIS-ISRIC data (Sub-regional soil data)
- **Project structure:**
    - WP1: Experiment implementation and data collection
    - WP2: Modelling
    - WP3: Writing of communication materials (policy briefs, articles, outreach materials, etc.)
    - WP4: Communication of results (policy brief, radio and TV broadcasts, etc.)
- **Expected results:**
- Simulation of carbon loss in cropping systems: projection by 2050 and 2063 (SOC will decrease to 16 g C/kg and to 14 g C/kg)
- Projection of future yields

Group members:

Adama Faye, Halima M. Diagne, Abdelkader L. Soule, Komla K. Ganyo

5. Network of crop modelers in West Africa: discussion

An open discussion on creating a network of crop modelers in West Africa was held with all participantsand facilitated by Dr. Anthony Whitbread (ILRI). From this discussion various proposals were made by the participants on the establishment and maintenance of a network of crop modelers in West Africa:

- Institutionalization : Create website and build a community of practices potentially linked to the

existing AGMIP WCA pages and list server.

- Define objectives and try to achieve and define activities and structure the network (define lead) and define goal
- Organize scientific meeting every two months to maintain the network active and or organize more training sessions
- For dissemination approach, create a blog and include other peoples who are interested on crop modelling for more impact
- Create a community for assistance in practices of crop modelling : Create link between people, help for self-training, set online training, facilitate an online forum where people can share problems and solutions, continue the training
- Join AGMIP community of practices in a long term

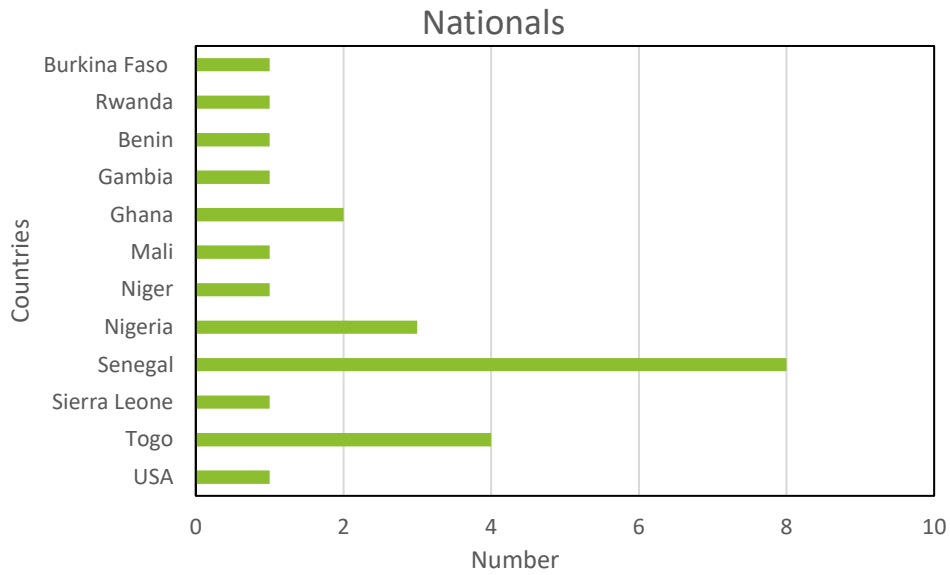
6. Visit to Bambey research station and farmers' fields

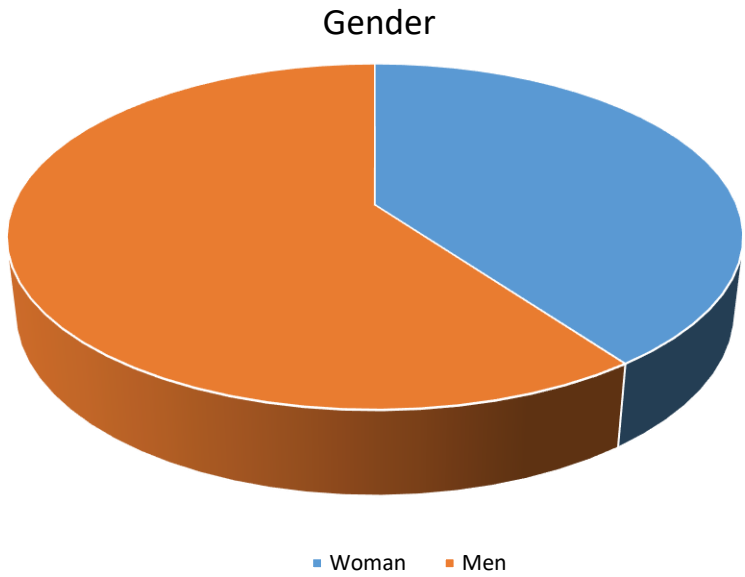
The field trip to Bambey aimed to expose participants to various research activities carried by the CNRA. Thus, after a welcome message from the Director of the CNRA, Dr. Ibrahima Sarr, the participants proceeded to visit the various experiments of Dr. Aliou Faye. During this visit, he presented the different technologies experimented on the field including high and low population tests, different fertilisation strategies among others. The demonstration park comprising different technologies of ISRA was also visited.

This visit to the CNRA research station was followed by a visit to the fields of farmers in the village of Keur Coly Thiaw, not far from the CNRA. In this village, the group visited two farmers' fields where a set of innovations are piloted by Dr Aliou Faye in the framework of the AICCRA project. These innovations refer to the increased of sowing density, integrated soil fertuility options including organic fertilizer sources etc.. This visit was also the subject of interesting discussions between the researchers and farmers.

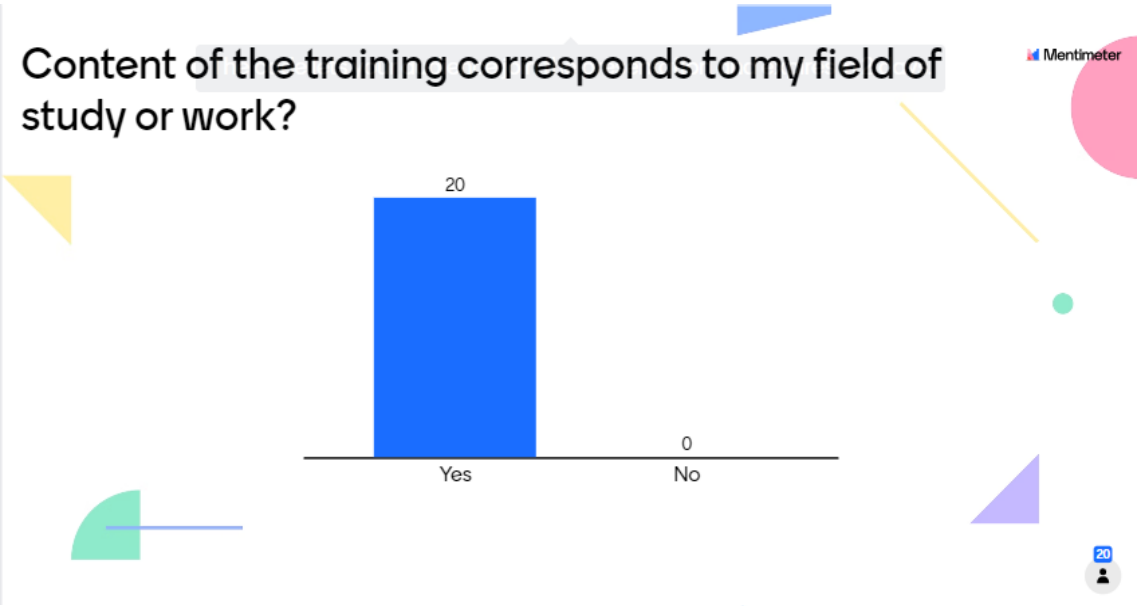
Photo 3: Group photo during field visit to CNRA, Bambey and farmer's field at Keur Coly Thiaw

Annex 1 : Trainees profiles





Annex 2: Training evaluation



The balance between theoretical and practical contributions

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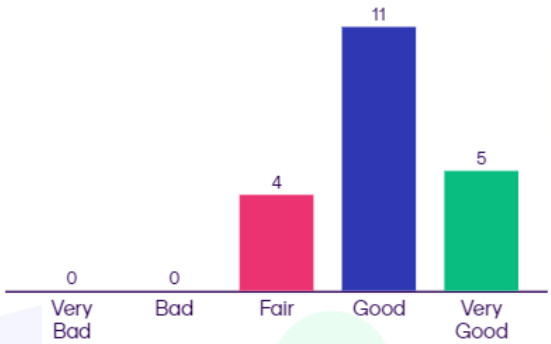

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How would you rate this course?

Mentimeter

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Would you have preferred the training to cover at least one topic in detail. If yes which ?

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- Sustainable intensification assessment
- APSIM
- Crop models in climate change impact assessment
- Apsim
- crop models manipulation
- Pratical session on APSIM
- Practical session on the use of some model package
- Praticable session on crop models
- Conception of crop model
- crop model setup for large scale modeling
- dynamic simulation modelling
- Collaboration and networking

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How do you feel now?

Mentimeter

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Annex 3: Training program

Date & time	Timing	Topic (format)	Responsible
Sunday, Sept. 11	12:00-13:00	Lunch	Organizing team
	13:00-13:30	Welcome and Introductions (ice-breaker format)	Organizing team
	13:30-14:00	Intro to the course: overview, learning outcomes, expectations (presentation + discussion)	Dr (Mrs) Omonlola N. Worou (ILRI)
	14:00-17:30	Optional APSIM refresher course	Dr Akinseye Folorunso, Dr (Mrs) Madina Diancoumba (ICRISAT)
Monday, Sept. 12	8:30-9:00	CERAAS Official welcome from Acting Director	Dr Aliou Faye (CERAAS)
	9:00-10:00	Opening talk: Sustainable intensification and climate risk in West Africa	Dr Abdramane Wane (ILRI)
	10:00-10:30	Coffee break and Group photo	Organizing team
	10:30-11:30	Lecture: Introduction to systems' analysis and modelling	Dr Marc Corbeels (IITA)
	11:30-13	Lecture: Crop models in climate change impact assessment an overview (including crop response to climate)	Dr (Mrs) Dilys MacCarthy (University of Ghana)
	13:00-14:00	Lunch	Organizing team
	14:00-15:00	Project work: define the problem within groups	All
	15:00-17:30	Tutorial #1, Modelling best practices: 1. How to create a met file; 2. How to create a soil file; 3. Calibration (rotating groups)	Dr (Mrs) Madina Diancoumba, Emmanuel Jacob, Dr Akinseye Folorunso (ICRISAT, ILRI)
Tuesday, Sept. 13	8:30-9:30	Lecture: Current state of crop models for assessing risk from climatic extremes	Dr (Mrs) Heidi Webber (ZALF)
	9:30-10:30	Lecture: Beyond the field scale: farm and landscape level perspectives	Dr David Berre (CIRAD)
	10:30-11:00	Coffee break	
	11:00-12:00	Lecture: Communicating impact assessments	Dr Joshua Aboah (ILRI)
	12:00-13:00	Tutorial #1, Modelling best practices continue: 4. Sensitivity analysis (rotating groups)	Dr Akinseye Folorunso, Dr (Mrs) Madina Diancoumba, Emmanuel Jacob (ICRISAT, ILRI)
	13:00-14:00	Lunch	Organizing team
	14:00-15:30	Project work: which model, data, and analysis?	All
Wednesday, Sept. 14	8:30-9:30	Lecture: Modelling soil carbon and nitrogen dynamics	Dr Marc Corbeels (IITA/CIRAD)
	9:30-10:30	Lecture: Modelling agroforestry systems	Dr Florent Noulèkoun (University of Korea)
	10:30-11:00	Coffee break	

	11:00-12:00	Lecture: Crop models to assess sustainable intensification practices (e.g. residue management, rotations, fertilization, Intercropping)	Dr Babacar Faye (USSEIN)
	12:00-13:00	Facilitated discussion: Limitations of crop modeling approaches and alternate approaches	Dr Marc Corbeels (lead), all
	13:00-14:00	Lunch	Organizing team
	14:00-14:30	Project work Project status and questions round	Dr Babacar Faye (USSEIN)
	14:30-17:00	Project work	
Thursday, Sept. 15	8:30-9:30	Lecture: Using models for informing farm level decision-making and scaling using ICT	Dr Anthony Whitbread (ILRI)
	9:30-10:30	Lecture: Model-assisted design of cropping	Dr (Mrs) Madina Diancoumba (ICRISAT)
	10:30-11:00	Coffee break	
	11:00-12:00	Lecture: Crop model development – key processes	Dr (Mrs) Dilys MacCarthy
	12:00-13:00	Project work continues	All
	13:00-14:00	Lunch	Organizing team
	14:00-17:30	Project: methods & analysis (group work)	All
Friday, Sept. 16	07:30-08:30	Trip to SALY	Dr Nadine Worou (ILRI)
	8:30-10:30	Discussion: can crop models lead to impact? How can equity issues be assessed? What are the main shortcomings of their use in West Africa? What developments are most urgently needed? What is most limiting to using crop models in your workplace? Research? (Facilitated group discussion)	All -> 2-3 groups to see if this session can be organized to create a position paper
	10:30-11:00	Coffee break	
	11:00-13:00	Discussion: Network of crop modelers in West Africa	All
	13:00-15:00	Lunch and Jummah prayer	
	15:00-17:30	Project: finalize analysis & prepare communication/dissemination plan (group work)	Participants
Saturday, Sept. 17	8:00-12:00	Visit Bambey research station and coffee break	Dr Akinseye Folorunso (ICRISAT/CERAAS)
	12:00-13:00	Trip to CERAAS	Participants
	13:00-14:00	Lunch	Organizing team
	14:00-16:00	Project: Presentations, including reflections on the learning process	All
	16:00-16:30	Feedback from participants	

AICCRA
Accelerating Impacts of CGIAR Climate Research for Africa

CGIAR

About AICCRA

Accelerating Impacts of CGIAR Climate Research for Africa (AICCRA) is a project that helps deliver a climate-smart African future driven by science and innovation in agriculture.

It is led by the Alliance of Bioversity International and CIAT and supported by a grant from the International Development Association (IDA) of the World Bank.

Discover more at aiccra.cgiar.org

VolkswagenStiftung

zalf Leibniz-Zentrum für Agrarlandschaftsforschung (ZALF) e.V.

ICRISAT
INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS