1. **GLDC-FP3 – Bayala Jules**

2. **Evaluating the impact of GLDC-based farming systems on natural resources health**

1. Background

In the drylands, the production is mostly based on cereal-legume-livestock-tree farming systems associating complementary components managed by rural households for the provision of staple food, marketable commodities, income, feed, manure, fuelwood and work-power. The cereals are usually grown in rotation or as intercrops with grain legumes (Vandermeer 1989; Brooker et al. 2015). The choice of these crops by farmers is due to their ecological suitability to dryland agriculture, critical attributes with the projected impacts of climate change (Adhikari et al. 2015; Daryanto et al. 2017). These cereal and legume crops are complementary for balanced diets; cereals providing starch while grain legumes are rich sources of protein, low in saturated fat, as well as possessing important micronutrients like zinc, folate and calcium and tocopherols (Seena et al. 2005; Akinyele et al. 2015. Besides the nutritional aspect, grain legumes, in rotations or as intercrops, introduce nitrogen into low input agroecosystems (Garg and Geetandjali 2007). Through litter and manure respectively, trees and livestock are contributing to maintain or restore soil fertility, mainly soil carbon (Bayala et al. 2006; 2019; Thornton and Herrero 2015). Therefore, projects promoting similar integrated farming systems will leverage the advantages of improved varieties to ensure the synergies of cereals, when grown in rotation or intercrops with grain legumes and integrated with trees and livestock. The hypothesis posited is that agroecologically-adapted, functional, diverse and emerging GLDC-based agricultural production systems will generate the agricultural, ecosystem and household returns required to achieve sustainable and resilient futures for the drylands. FP3 is combating land degradation by moving to more resilient and resource conserving production systems. With locally adapted crop, tree and livestock solutions this flagship aims to contribute to restoring degraded lands and efficient use of scarce water resources for sustainable and productive agro-ecosystems. However, the challenge remains how to assess the impacts of GLDC-based farming systems on natural resources sustainability. We anticipate that participatory social and ecological analysis on the relevance of the integrated portfolios of GLDC and crop-tree-livestock-based management options will help understand to which extent farmers, development actors and policy makers are less averse to changing farm production systems and components. Therefore, the system performance will go here beyond yield to include how better the land is managed and maintained (Tittonel et al. 2010; Vanlauwe et al. 2014; Rockström et al. 2017). The present activity is about evaluating the impact of development that promoted integrated farming at plot, farm and landscape levels by assessing ecosystem services delivery and flow across spatial and temporal scales. This will also include trade-off analyses to identify optimum strategies for complementarities and conflicts at both household and landscape levels.

2. Methodological approaches

The study will adopt a three scales approach including plot, household and landscape to fully assess the social and biophysical aspects of the interventions. The current phase of GLDC only has two years of direct activities and therefore doesn't provide long-term interventions for assessing impacts on natural resources. However, mapped projects that have promoted similar cropping systems and interventions can be used for such investigation. The Dutch funded Drylands Development Program (DryDev) and the associated IFAD-EU Land Restoration project provide an excellent dataset and field interventions to assess the situation before and after across the above three mentioned scales.

For security reasons, we will evaluate the following intervention sites of DryDev: Kyon in Burkina Faso and Yorosso in Mali.

A reduced number of variables from LDSF methods will be measured including:

- Land management: land use units
- Vegetation cover
- Land degradation: erosion prevalence;
- Soil hydrology: infiltration
- Soil health: organic carbon concentration and stocks.

2.1. Landscape level assessment

The entry point will be a multi-date (3 dates) analyses of the land use types and land health characteristics: five years before the start of the project (2009), just at the beginning of the project (2013) and now (2020). This analysis will make use of remote sensing to depict the changes in land uses, tree cover, erosion, soil health, soil hydrology and how and in which direction the project interventions have impacted them. This analysis will be based in part on the Land Degradation Surveillance Framework (LDSF) database which has been applied at over 30 sites in West Africa. Ground vegetation surveys, using the LDSF, and additional modules specific for land cover change assessments, will also be conducted using stratified sampling of the land use types identified by the GIS work. The LDSF assesses both tree and shrub densities and diversities across landscapes.

The data collected from this survey will serve to evaluate the aboveground biomass and carbon storage of vegetation within the different land use types and their dynamics. This will be done using non-destructive allometric equations to estimate the biomass in the woody vegetation of the different units and scale up to the village (Chave et al. 2005, 2014). These equations express tree biomass as a function of easy-to-measure parameters such as diameter at breast height (DBH), height, or wood density or combination of these as single predictors (Brown 2002; Chave et al. 2014). The equations can be developed for estimating biomass of specific species, or a mix of species from a region. In the literature there are allometric equations developed for some economically important tree species, but the vegetation of a village territory is mostly multi-species and requires mixed species equations developed with data that covers the diversity of the trees to be measured (Henry et al. 2011). In drylands such equations are lacking, hence general equations such as those reported in Chave et al. (2005, 2014) are commonly used for estimation of biomass for general purposes (Dimobe et al. 2018).

2.2. Plot level assessment

This component will examine the resource base and impacts of local use on key forest/tree products and environmental services from these landscapes. A combination of ground survey (LDSF) and remote sensing (previous activity) will be used to evaluate how change is affecting land use and the provision of environmental services, including soil carbon, soil erosion, infiltration capacity, among others (Vågen et al. 2013, 2018; Winowiecki et al. 2016, 2017, 2018). It will describe the biophysical characteristics of the resources used, the extent to which they provide environmental services but also are affected. Therefore, three-date (2009, 2013 and 2020) maps developed in the previous activity will help localize plots cropped before the project, at the beginning, cropped now and finally plot which have never been cropped during the three dates. LDSF will be applied on these four different plots to assess soil quality including soil carbon.

2.3. Community and Households surveys

Research at the village and household level will analyze the impacts of GLDC-based farming systems at these scales. Data collection will include village level focus group interviews (gender-disaggregated) to understand historical trends, population change, land use patterns, decision-making institutions and the customary and formal property rights systems. In addition to existing data that we will use, a household survey will characterize livelihoods and livelihood variation across villages in the selected sites. The survey will assess household characteristics, the interconnections between GLDC-based farming and the natural resources management. A stratified sample will ensure the inclusion of different social categories such as gender and age. Information from the focus groups and household survey will allow in-depth systematic analysis and description of socio-economic function of these integrated smallholder systems and provide a key basis for improving the understanding of them by policy makers and other outsiders. Policy analysis will evaluate how existing legal frameworks and formal institutions produce constraints and opportunities for smallholder livelihoods within GLDC-based farming landscapes and whether key adaptive features are affected. Individual interviews will be conducted to collect the information about the view of each household on land use dynamics, the impact of project interventions on land use dynamics and the provision of ecosystems services include yield and soil fertility (quality). The findings of the individual survey will be synthesized and presented in group discussions at the site level and finally at the regional level to collect the contribution of expert persons.

3. Expected outputs

The key expected outputs are:

- Maps of land use change, and drivers of these changes identified;
- Current aboveground biomass assessed for various land use types;
- Potential changes (not direct for the dates before today) in above ground biomass evaluated;
- Soil fertility status including soil organic carbon content across the various land use types and cropping systems evaluated;
- Provision of ecosystem services to the local population;
- Influence of the various interventions on natural resource base assessed and understood;
- Datasets available online via Harvard Dataverse curated.

3. References

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Qualifications

1. The lead candidate must hold a remote sensing (MSC but preferably PhD)
2. Have good knowledge about biomass and carbon evaluation in the landscape
3. Be able to product the report in good English
4. Understand and speak French
5. Be immediately available