ARTICLE IN PRESS

AGSY-02269; No of Pages 11

Agricultural Systems xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

Agricultural intensification scenarios, household food availability and greenhouse gas emissions in Rwanda: Ex-ante impacts and trade-offs

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ARTICLE INFO

Article history:
Received 15 February 2016
Received in revised form 11 February 2017
Accepted 14 February 2017
Available online xxxx

Keywords:
Climate smart agriculture
Low carbon development
Household modeling
Sustainable intensification
Ex-ante impact assessment
Sub-Saharan Africa

ABSTRACT

Rwanda's agricultural sector is facing severe challenges of increasing environmental degradation, resulting in declining productivity. The problem is likely to be further aggravated by the growing population pressure. A viable pathway is climate smart agriculture, aiming at the triple win of improving food security and climate change adaptation, while contributing to mitigation if possible. The Government of Rwanda has initiated ambitious policies and programs aiming at low emission agricultural development. Crop focused policies include the Crop Intensification Program (CIP) which facilitates access to inorganic fertilizer and improved seeds. In the livestock subsector, zero-grazing and improved livestock feeding are encouraged, and the Girinka program provides poor farm households with a crossbred dairy cow. In this study, we aimed at assessing the potential impact of these policy programs on food availability and greenhouse gas (GHG) emissions of 884 households across different agro-ecologies and farming systems in Rwanda. Household level calculations were used to assess the contribution of current crops, livestock and off-farm activities to food availability and GHG emissions. Across all sites, 46% of households were below the 2500 kcal MAE^{-1} yr^{-1} line, with lower food availability in the Southern and Eastern Rwanda. Consumed and sold food crops were the mainstay of food availability, contributing between 81.2% (low FA class) to 53.1% (high FA class). Livestock and off-farm income were the most important pathways to higher FA. Baseline GHG emissions were low, ranging between 395 and 1506 kg CO_2e hh^{-1} yr^{-1} per site, and livestock related emissions from enteric fermentation (47.6–48.9%) and manure (26.7–31.8%) were the largest contributors to total GHG emissions across sites and FA classes. GHG emissions increased with FA, with 50% of the total GHG being emitted by 22% of the households with the highest FA scores. Scenario assessment of the three policy options showed strong differences in potential impacts: Girinka only reached one third of the household population, but acted highly pro-poor by decreasing the households below the 2500 kcal MAE^{-1} yr^{-1} line from 46% to 35%. However, Girinka also increased GHG by 1174 kg CO_2e hh^{-1} yr^{-1}, and can therefore not be considered climate-smart. Improved livestock feeding was the least equitable strategy, decreasing food insufficient households by only 3%. However, it increased median FA by 755 kcal MAE^{-1} yr^{-1} at a small GHG increase (50 kg CO_2e hh^{-1} yr^{-1}). Therefore, it is a promising option to reach the CSA triple win. Crop and soil improvement resulted in the smallest increase in median FA (FA by 322 kcal MAE^{-1} yr^{-1}), and decreasing the proportion of households below 2500 kcal MAE^{-1} yr^{-1} by 6%. This came only at minimal increase in GHG emissions (23 kg CO_2e hh^{-1} yr^{-1}). All policy programs had different potential impacts and trade-offs on different sections of the farm household population. Quick calculations like the ones presented in this study can assist in policy dialogue and stakeholder engagement to better select and prioritize policies and development programs, despite the complexity of its impacts and trade-offs.

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http://dx.doi.org/10.1016/j.agsy.2017.02.007

1. Introduction

Agriculture is the backbone of Rwanda's economy, involving >80% of the population, and contributing 30% to the country's GDP. In Rwanda's Vision 2020, agriculture is considered one of the major potential catalysts for employment creation and transformative growth (MINECOFIN, 2000). 46.3% of the country's total land area (2.6 million ha) is arable, and main crops include beans, cassava, wheat, maize and rice. Permanent crops such as citrus, coffee and rubber, flowering shrubs, fruit trees, nut trees and vines occupy 9.5% of country's surface (NISR, 2014). However, Rwanda's agricultural sector is facing challenges of increasing environmental degradation, resulting in declining productivity. 34% of surveyed households said they are facing problems caused by environmental degradation, with erosion, reduced agricultural production and destructive rains being mentioned most often (NISR, 2011). The problem would be further aggravated by the growing population. If the current population growth rate of 2.8% sustains, Rwanda will reach 26 million inhabitants by 2050, translating to a population pressure of 1000 people per km^2.

Globally, agriculture is a principal source of climate change, directly contributing 14% of anthropogenic greenhouse gas (GHG) emissions, and another 17% through land use change. The majority of future increases in agricultural emissions are expected to take place in low- to middle-income countries (Smith et al., 2007). While industrialized countries have to dramatically reduce current levels of GHG emissions, developing countries face the challenge of finding alternative, low carbon development pathways. Climate-smart agriculture (CSA) is seen as one of these pathways, aiming at transforming agricultural systems towards the triple win of increased food security, climate change adaptation, and mitigation. However, it has been recognized that in developing countries, mitigation should be considered as co-benefit while priority lies with food security and adaptation (Lipper et al., 2014; Campbell et al., 2014). CSA is complementary with sustainable intensification (SI), which aims at increasing agricultural productivity from existing agricultural land while lowering its environmental impact. Increased resource use efficiency contributes to SI as well as CSA through increased productivity and reduced GHG emissions per unit output (Campbell et al., 2014). CSA and SI both acknowledge the importance of potential trade-offs between agricultural production and environmental integrity. A better understanding of these trade-offs is needed to reach a more productive and sustainable agricultural sector (Klapwijk et al., 2014a; Steenwerth et al., 2014; Kanter et al., 2016).

The government of Rwanda has recognized the dual challenge of food security and environmental sustainability, and has therefore put emphasis on generating an integrated suite of agricultural and environmental strategies, policies, institutions and funds. The Strategic Plans for the Transformation of Agriculture (Plan Strategique de la Transformation de Agriculture - PSTA), Volume III, covering 2014 - 2017 (MINAGRI, 2009a) and Rwanda's Vision 2020 (MINECOFIN, 2000) are designed to guide the fundamental transformation of Rwanda into a middle income country by 2020. One of the six pillars of Vision 2020 is a Productive and Market Oriented Agriculture, with Sustainable Natural Resource Management as cross-cutting theme (MINECOFIN, 2000). The cross-sector national strategy on Green Growth and Climate Resilience adds the environmental dimension, calling to address poverty and climate change concurrently (MINIRENA, 2011). Well-known agricultural policy programs aiming to implement the strategic aspirations are the Crop Improvement Program (CIP), which supports access to mineral fertilizer and improved seeds (MINAGRI, 2011); the Girinka program which provides crossbred cows to poor farmers under a pass-on system of payment and wealth transfer (MINAGRI, 2006); and the strategy for animal nutrition improvement which calls for adequate on-farm mix of forage legumes and grasses and concentrate feeds under zero grazing (MINAGRI, 2009b).

Ex-ante impact assessment can help decision makers in targeting and upscaling technological interventions. Farm household models have often been used for this purpose, although integrated analyses of food security at household level are still scarce (Van Wijk et al., 2014). A standard approach is to capture the diversity of farming systems with a limited number of farm types, often using resource endowment or production goals as clustering factors (e.g. Tittonell et al., 2010). Potential impacts are quantified for these farm types, and scaled up to population level by using information on the relative importance of each type. This study takes an alternative approach to assess potential impacts of policy oriented scenarios on food availability and GHG emissions across different agro-ecologies in Rwanda. Instead of focusing on few representative farm types, we apply relatively quick and simple calculations across a large number of households. The objectives of this study are therefore to i) quantify the baseline contribution of crops, livestock and off-farm activities to household food availability and GHG; ii) assess differences in contributions within and between locations and food availability classes; iii) and determine the impact, synergies and trade-offs of crop and livestock intensification policies on food availability and GHG.

2. Materials and methods

2.1. Baseline household survey and study sites

A household survey was conducted in June – December 2006 by the Consortium for Improvement of Agriculture-based Livelihoods in Central Africa (CIALCA) in Rwanda, DR Congo, and Burundi. In Rwanda, 911 households were surveyed across different administrative units and agro-ecologies (Fig. 1). The Birunga and Congo Nile Watershed Divide (CNWD) are highland areas between 1900 and 2500 m, with abundant rainfall, highly weathered soils, and expansive forest cover. The Bubereka highlands are a plateau at 2300 m altitude, and soils are generally more fertile than in the CNWD. The Central Plateau is a large region of hills and valleys of an average altitude of 1700 m and annual rainfall of 1200 mm, and its soils are suitable for a wide range of crops. The Eastern Plateau & Peripheral Bugesera are the extension of the Central Plateau into the drier East, with a hilly topography and moderate agricultural potential. The Eastern Savanna & Central Bugesera include the lowlands in the East (1250–1600 m) with 850–1000 mm annual rainfall, and the agricultural potential is lower. The Imbo area is characterized by high temperatures, abundant rainfall, good quality alluvial soils and possibilities for irrigation, which makes it conducive for intensive agriculture (Fig. 1; Verdoodt and Van Ranst, 2003). The survey collected quantitative information on the socio-economic status of households, agronomic characteristics of the farming system, market access and commercialization of crops, food security status and nutrition, and health of the household members (Ouma et al., 2012). 27 outliers were excluded from the analysis due to unrealistic fertilizer and crop production values, or missing crop land area data. The final database contained data of 884 households: 190 households in Bugesera, 200 in Kirehe, 196 in Nyagatare (all Eastern Province), 99 in Karongi, 50 in Rubavu, 50 in Rusizi (all Western Province), and 99 in Ruhango (Southern Province).

2.2. Food availability calculation

Food security encompasses various dimensions including food availability, food access, food utilization and food stability. Food availability in general refers to both caloric intake as well as nutritional requirements (Carletto et al., 2013a). In this study, we used a simple proxy for food security, which exclusively focusses on the energy component of food availability. The food availability (FA) indicator was developed from initial work by Hengsdijk et al. (2014), and first published by Frelat et al. (2016) who calculated FA for >13,000 households across sub-Sahara Africa. Ritzema et al. (2016) applied it to data from 1800 households in West and East Africa, illustrating its usefulness for potential impact assessment. FA is a potential supply indicator, representing the daily food energy availability per household member from consumption of farm produce and food purchases with on-farm and off-farm income. The FA indicator does not intend to fully account for all household expenses or nutritional requirements. For this study,

Please cite this article as: Paul, B.K., et al., Agricultural intensification scenarios, household food availability and greenhouse gas emissions in Rwanda: Ex-ante impacts and tr..., Agricultural Systems (2017), http://dx.doi.org/10.1016/j.agsy.2017.02.007