RUFORUM Working Document Series (ISSN 1607-9345) No. 14 (2): 355-360. Available from *http://repository.ruforum.org*

Research Application Summary

Influence of mountainous ecosystems in the production of Arabica coffee

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Abstract

The aim of this study is to gain an understanding of how land use intensity in high altitude areas and soil management influences abundance and diversity of natural enemies, including pests of coffee and influences on microclimate and soil characteristics of coffee systems. Further it aims at establishing the relationship between the delivery of ecosystem services and coffee productivity. The study will generate knowledge for better understanding of coffee agro-ecosystems for improved productivity amidst increasing population pressure, climate variability, declining soil fertility, and the range of pests and diseases in the highly vulnerable landscapes on the slopes of Mt Elgon in eastern Uganda. Recommendations will be made on systems with high potential for natural pest and disease control, climate change mitigation, improved soil characteristics and microclimate control. To achieve this, fixed factors namely; altitude, land use intensity, soil fertility management type, and the interaction between the factors will be included in a generalized linear model with species richness, diversity and abundance of agents of ecosystem services (pest control agents, decomposers) in coffee fields, and with coffee yield parameters as dependent variables in the analyses of variance. For tests to establish the relationship between species richness and abundance of the agents of ecosystem services and the environmental variables and/or yield, multivariate analysis tools of Principal Component Analysis and Discriminant Analysis will be used.

Key words: Arabica coffee, ecosystem services, landuse, Mt. Elgon, soil fertility management, Uganda

Résumé

L'objectif de cette étude est de comprendre comment l'intensité de l'utilisation des terres dans les zones de haute altitude et la gestion des sols influencent l'abondance et la diversité des ennemis naturels, y compris les ravageurs du café et les influences sur le microclimat et les caractéristiques des systèmes de café. En outre, il vise à établir la relation entre la prestation des services écosystémiques et la productivité du café. Cette étude générera des connaissances pour mieux comprendre les agroécosystèmes du café afin d'améliorer la productivité au milieu de l'augmentation de la pression démographique, de la variabilité climatique, de la baisse de la fertilité des sols et de la gamme des ravageurs et des maladies dans les paysages très vulnérables sur les pentes du Mt Elgon,

Des recommandations seront formulées sur les systèmes à fort potentiel de lutte contre les ravageurs et les maladies naturelles, l'atténuation des changements climatiques, l'amélioration des caractéristiques du sol et le contrôle du microclimat. Pour y parvenir, des facteurs fixes, à savoir l'intensité de l'utilisation des sols, le type de gestion de la fertilité des sols et l'interaction entre les facteurs seront inclus dans un modèle linéaire généralisé avec la richesse en espèces, la diversité et l'abondance des agents des services écosystémiques (agents antiparasitaires, décomposeurs) dans les champs de café comme variables dépendantes dans les analyses de variance. Pour les tests visant à établir la relation entre la richesse en espèces et l'abondance des agents des services écosystémiques et les variables environnementales et / ou le rendement, des outils d'analyse multivariée de l'analyse des composantes principales et des analyses discriminantes seront utilisés.

Mots clés: café arabe, services écosystémiques, utilisation du sol, Mt. Elgon, type de gestion de la fertilité des sols, Ouganda

Background

Coffee is the world's most valuable tropical export crop with an annual retail value of approximately US $ 90 billion (DaMatta *et al.*, 2007; Jaramillo *et al.,* 2011), and a vital source of foreign exchange earnings for Eastern and Central Africa countries (Rutherford, 2006). Uganda is the second largest producer of coffee in Africa with over half a million households depending on coffee for livelihood (Van Asten *et al*., 2011). In 2013, Uganda produced a total of 232,561 tons of coffee (UBOS, 2014). Approximately 40% of coffee export value in Uganda is attributed to Arabica coffee though significant inter-annual variations occur depending on crop yields and price fluctuations (Jassogne *et al*., 2013). Arabica is predominantly grown in highlands such as on the slopes of Mount Elgon, Mt. Rwenzori and Mt. Muhavura and areas above 1400 m.a.s.l although this altitude threshold could increase if temperatures rise (Jassogne *et al.,* 2013). The Mount Elgon region located in eastern Uganda is Uganda's largest Arabica producing area.

In Uganda, coffee is grown by smallholder farmers (Mafusire *et al.*, 2010) as a monocrop or an intercrop with mainly banana, other traditional food crops and shade trees. Coffee – banana intercropping is common in densely populated areas (Van Asten *et al.*, 2011), and usually grown with shade on the lower slopes and without shade on the highest slopes (Soini, 2007). Arabica coffee production is declining due to a combination of several factors including inappropriate land use decisions, climate change variability, declining soil fertility, ravages of pests and diseases, a dwindling resource base, and market uncertainties (Ecotrust, 2012; Jonsson *et al*., 2014). Proper land use management options provide the opportunity to improve ecosystem services and enhance coffee yields thereby offering relief from environmental shocks and improving farmer livelihoods. In this paper we review some of the effects of agricultural intensification on biodiversity and provision of ecosystem services such as biological control and nutrient cycling.

Key Concerns on Mountainous Ecosystems and Coffee Production

The current challenge in the region is to meet the food and fuel demands of a growing population by enhancing the productivity of the local agricultural systems without damaging the ecosystem services provision. Mountain ecosystems are one of the most fragile but significant ecosystems providing invaluable benefits to humans both in natural and economic aspects through the various ecosystem services and products (Mugagga *et al*., 2012; Jiang *et al.*, 2014). Various agricultural intensification has negatively impacted on wide range of ecosystem services including; water quality, pollination, nutrient cycling, soil retention, carbon sequestration, and biodiversity resulting in adverse feedbacks on climate, food security and on-farm income (Winkler Prins and Sandor, 2003; Jaramillo *et al.*, 2011).

Highlands have considerably inherent fertile soil due to the young volcanic soil and are sources of water points suitable for agriculture. However, these soils are rapidly losing their quality as a result of intensification of land use to meet the food and fuel demands of growing human populations. Studies have shown that Mount Elgon region, the largest Arabica coffee producing area in East Africa, is among the most severely degraded (Knapen *et al.,* 2006; Mugagga *et al.,* 2013). This resulted from land use changes where large areas of forest have been converted to agricultural fields without sustainable management, and the resultant increased incidences of landslides and emerging cracks.

Studies have further shown that clearing natural vegetation to grow crops can result in flareups in pests, by affecting the functioning of natural pest control because non-crop habitats provide requisites for a broad spectrum of natural enemies (Tscharntke *et al*., 2005; Bianchi *et al*., 2006). Pests and diseases are responsible for losses of approximately 30% to 40% of the total coffee production (Reid *et al.*, 2005; Lin, 2010) and this is more so for Arabica coffee than Robusta (Rutherford and Phiri, 2006). Existing natural enemies can prevent many plant-feeding insects from achieving pest status if the environment is favorable (Charlet *et al*., 2002).

Effects of land degradation and subsequent decline in biodiversity has exacerbated the effect of climate change on agricultural production. Many studies have predicted that climate change will have a massive impact on the coffee growing regions of Uganda (Haggar and Schepp, 2011; Jassogne *et al*., 2013). The climate change mapping showed that areas suitable for growing Arabica coffee will reduce drastically in the future and losses induced by climate change are estimated to reach tens of millions of US$ annually (Jassogne *et al.*, 2013). Climate change could directly affect Arabica coffee during flowering and bean filling, and indirectly due to the appearance or increasing incidence of certain pests and diseases (Jassogne *et al*., 2013). In fact, Jonsson *et al.* (2014) showed the performance of the coffee berry borer to increase with increasing temperatures.

Enhancement of Biodiversity and ecosystem services by Agriculture

Proper agricultural management has the potential to enhance biodiversity and ecosystem functions (Rosenzweig, 2003; Tscharntke *et al*., 2005). On the other hand, agriculture is dependent upon the functioning of environmental processes for delivering goods and services. Arabica coffee systems in Mt Elgon area are characterized by mosaics of natural and semi natural vegetation and this may mitigate the negative effects of tree loss and can complement the protection of forest ecosystems through provision of fuel. Coffee agroforestry can provide maintenance of biodiversity, watershed services, soil fertility, natural enemy conservation and resilience to climate change effects through creating a suitable microclimate (Jassogne *et al.*, 2013). However, there has not been enough focused in-depth studies to assess the effect of the intensity of non-crop vegetation, solely or blended with biophysical aspects and other pertinent on-farm practices on delivery of ecosystem services and productivity in the coffee growing areas of Uganda. Hence the rationale for the on-going study which has just been intiated.

Study Description

The study is being conducted in two districts of Kapchorwa and Sironko within the Mount Elgon region of Uganda. The study involves a one year longitudinal biological monitoring survey of well-established farmer coffee fields. A total of 72 sites have been purposively selected based on ecosystem system service drivers, i.e., land use intensity and Altitude.

Study sites were clustered by altitude into the upland (1800m and above), midland (1500m-1800m) and lowland (<1500m). For each cluster, 12 farmer fields will be selected making a total of 36 farms per district. The farmer fields were then purposively selected based on land use intensity defined by cropping intensity to include four categories: Coffee monocrop, Coffee+ annual crop, coffee + banana, and coffee+banana+shade trees. Semi-natural vegetation proximate to the selected coffee fields (High > 40 %; medium 11-40 %, and low < 10 %) will be scored following (Diekotter *et al.,* 2010). Semi-natural habitats include fallows, hedgerows, field margins, grasslands, roadsides, woodlands/woodlots, track-sides, and stream-edges. In addition soil management practices will be considered as a factor also nested within cropping system and will be categorized according to i) usage of organic manure (compost or mulch), ii) mineral fertilizer usage, iii) cover cropping, iv) contouring/ridging, and v) no soil management. This information will be collected using a separate checklist.

Data are being collected in the coffee fields following standard procedures for insect pests, natural enemies and decomposers as indicators of ecosystem services delivery (biological control and nutrient recycling). Data will also be collected on soil characteristics (soil moisture, temperature, organic matter, pH, and macro and micronutrients) and microclimate within plantations (relative humidity, ambient temperature, light intensity) following standardized procedures. Data will also be collected on flower intensity, number of fruiting internodes, fruit setting and coffee bean yield.

Future Research

Research is needed to provide a better understanding of the coffee agro-ecosystems in montane areas and develop viable recommendations aimed at improving the productivity of Arabica coffee in Uganda and related ecosystem. There is need to design ecosystem management practices and enhamce biodiversity concervation , curtail pest and disease outbreaks and mitigate the likely climate change and variability impacts.

Acknowledgement

This research is being funded by RUFORUM under Call ID: RU/CGS/GRG/21/07/14. This paper is a contribution of the 2016 Fifth African higher education week and RUFORUM Biennial Conference.

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