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Remote sensing based and participatory Analysis of land degradation and potential land conservation measures in Kloto District (Togo, West Africa)

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Abstract: This study investigates proximate drivers of cropland and forest degradation in Kloto district (Togo, West Africa) as, way of, exploring integrated sustainable landscape approaches in respect to socio-economic and environmental needs and requirements. Net change analysis of major cash and food crops based on three time steps Landsat data (1985–2002, 2002–2017 and 1985–2017) and quantitative analysis from participatory survey data with farmers and landowners are used. Study underlines poor agricultural systems and cassava farming as major impediments to alarming forest losses between 1985–2017. Significant net loss in forests cover by 23.6% and surface areas under cultivation of cocoa agroforestry and maize by 12.99 and 10.1% from 1985 to 2017, due to, intensive cassava cropping (38.78%) and settlement expansions (7.84%). Meanwhile, loss in forest cover between 2017 and 2002 was marginal (8.36%) compared to the period 1985–2002 for which the loss was considerable (15.24%). Based on participatory surveys, majority of agricultural lands are threatened by erosion or physical deterioration (67.5%), land degradation or salt deposits and loss of micro/macro fauna and flora at 56.7%, declining in soil fertility (32.5%), soil water holding capacity (11.7%) and changes in soil texture (3.3%). Majority of farmers adhere to the adoption of the proposed climate smart practices with emphasis on cost effective drip irrigation systems (45.83%), soil mulching (35%) and adoption of drought resilient varieties (29.17%) to anticipate drought spells adverse. The study concludes that low adoption of improved soil conservation, integrated water management and harvesting systems and low productive and adaptive cultivars entail extreme degradation of croplands and crops productivity decline. Therefore, farmers are forced to clear more forests in search of stable and healthy soils for production and extraction of forest products to meet their food demands and improve their livelihoods conditions. Capacity building on integrated pathways of soil and land management practices are therefore needed to ensure sustainable and viable socio-ecological systems at local scale.

Keywords: Land degradation, Food security, climate change, Remote sensing, survey datasets, Kloto District

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1. Introduction

Participatory integration of forests, agriculture and sustainable development is fundamental to maintain and sustain natural ecosystems, food security while adapting and mitigating climate change. Deforestation and forest degradation is one of the chief contributor to climate change and ecosystem losses. In Agriculture, Forestry and Other Land Use (AFOLU) sectors, agriculture remains the sole impediment to forests sustainability due to population growth and its incessant needs for food, energy, water, shelter, etc. With a global total area of nearly 4 billion hectares (30% of the Earth surface cover), forests play tremendous role when it comes to carbon cycling and ecosystem sustainability in changing climate (Cramer et al., 2004; Van Der Werf et al., 2009; Saatchi et al., 2011; IPCC, 2014). Recently, the population growth associated to the increase in food demand, socio-economic orientations of countries and political decisions underpin the alarming loss of forests worldwide, especially in developing countries. A case study in Cameroon and Congo revealed that, institutional and policy factors are predominant to combat deforestation and forest degradation (Tegegne et al., 2016). Keenan et al. (2015) posited significant net shrinking in forest areas from 4128 to 3999 Mha between 1990 to 2015 mainly in the tropics with highest rate loss in low income countries based on the statistics of Global Forest Resources Assessment (FAO, 2015). Consequently, it is estimated, according to Houghton (2005) and Gibbs et al. (2007) that 1 to 2 billion Mg of carbon are released per year as direct consequences of deforestation. 15 – 25% of annual greenhouse gas emissions emanated from tropical deforestation and forest degradation and nearly 33% of climate mitigation and adaptation talks emphasis on forests sustainability. To such, the United Nations institutional organs (e.g. UNCCD, UNEP, UNFCCC, FAO) and affiliated research centers (e.g. CIFOR, WWF, ICRAF) bold an ambitious plan to halt deforestation and forest degradation, protect and promote forests reserves, restore degraded forests ecosystems and improve capacity building on integrated forests and agriculture landscape management.In West Africa, and especially in Togo, forest loss and deforestation are acute environmental challenge occurring at some unprecedented rate forest ecosystems. The annual deforestation is alarming with up to 4.5% where, forests recover rates nearly 24.24% (www.reddtogo.tg). Deliberate expansion of croplands entails significant degradation of native forestlands in association with total conversion of forest areas to croplands mainly for cash (cocoa agroforestry, coffee, teak, oil palm production) and food (rice, maize and cassava cropping) crops in forest zone (koglo et al., 2018: in press). These conversions drive on-site (e.g. soil degradation, loss of life and biodiversity, property destruction) and off-site (e.g. greenhouse gas emissions, climate change and global warming) drawbacks. Relevant works on forests dynamics in changing climate, its roles, drivers, policies and reliable methods for their monitoring are duly undertaken and span across the globe from simple remote sensing (e.g. Rawat and Kumar, 2015; Rawat et al., 2013; Folega et al., 2014; Badjana et al., 2014; Butt et al., 2015; Dimobe et al., 2015) to intensity analysis (e.g. Pontius et al., 2004; Aloô and Pontius, 2008; Gao et al., 2016; Diwediga et al., 2017). However, little attention is paid to integrating satellite data for the evaluation of existing farming and cropping systems through survey datasets where, land utilization by farmers, predominant farming and cropping systems in use and willingness to sustainable land management practices adoptions (e.g. soil and water conservation) are fully assessed. This avenue of research is essential in achieving sustainable socio-ecological landscapes through integrated and participatory assessment, opportunities and policies identification and formulations to circumvent forests cover shrinking under climatic and anthropogenic threats. Sustainable ecosystem management entails coherent and integrated approach across all agricultural sectors and food systems through an inclusive process with farmers and rural people whom, will adhere to the plans if they meet their needs and interests (FAO, 1993, 2010, 2016). From the foregoing introduction, this paper aims to assess proximate drivers in terms of (i) net change analysis of cash and food crops and residential expansions; (ii) Farmers characteristics, actual farming and cropping systems in changing climate and (iii) willingness to adopt integrated soil and water resource practices to mitigate croplands and forests degradation and adapt to the climate change adverse.

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2. Materials and Methods

2.1. Study Area

The study was conducted in Kloto district which encompasses 13 sub-districts located in the South West of Capital Lomé (Figure 1). Kloto lies between $0^{o}30'0''$ and $0^{o}46'30''$Longitude East and $6^{o}45'0''$ and $7^{o}6'0''$ Latitude North and approximates 528.23 km^2. The major economic activity is farming of mainly food crops (e.g. maize, cassava) and cash crop (cocoa and coffee agroforestry). The average production of maize and cassava from 1990 to 2016 revealed an annual production of 10,928 and 19,498 tons for maize and cassava over an area of 8,291 and 3,080 hectares respectively. From 2014 to 2016 cocoa agroforestry of 2,762 hectares produced 1,041 tons annually (DSID, 2017: analyzed statistic data). The average annual rainfall over 16-year total rainfall period is 1517.1 mm ($CI_{0.95}$ = 1517.1±108.1 mm). The highest and lowest annual rainfall of 1830 mm and 1063 mm were recorded in 2016 2005 respectively. The study area has 20.5±0.11°C and 28.9±0.22°C as minimum and maximum 16-year mean temperature, respectively. The lowest minimum temperature (20.3°C) was recorded in 2001, 2008, 2014 and 2015 with highest (21.1°C) in 2016. The sunniest year was 2016 with 29.5°C maximum temperature.

2.2. Data Collection and analysis

Three Landsat data (5, 7 and 8) of March 1985, 2002 and April 2017 were downloaded from USGS website with cloud cover less than 10 % using path 193 and row 055. For the selected years, we assumed the same phenological conditions prevailed at the acquisition date because of the bimodal climate season in the study area. Thereafter, thematic analysis was performed in ENVI software based on six (06) Land Use Land Cover types namely: forest, cocoa agroforestry, maize, cassava farms, settlements and unclassified (Table 1).

Table 1. Land use land cover type list

Land use land cover type	Definition	Source
Forest	areas covered with original vegetation of different tree species of a minimum height of 5m at maturity with 30% crown cover with minimum area spanning of 0.5ha.	IPCC (2006)
Cocoa agroforestry	perennial arable and tillable land of mixing cocoa, trees and other crops (plantains) under conventional and family cropping systems.	
Cassava	Annual / perennial arable and tillable land of local or improved cassava under conventional and family cropping systems	Authors definition
Maize	annual arable and tillable land of improved maize (Ikenne or Obantapa) variety under conventional and family cropping systems	
Settlement	areas cover with human habitations where tree cover is negligible	
Other	Places occupied by e.g. road, water	

Forty (40) random points were collected for each land use type to train and validate the classification. Image calibration of the three years was done using ground truth (survey data), archived land occupational georeferenced points (40 in total) of each land use type of the subsequent years from available statistics (DSID, 2017: Agriculture Census statistic data) and Google Earth historical data records. Supervised classification was done using Maximum Likelihood Classifier and post classification technique was initiated to derive the extended cross tabulation matrix for land use change and intensity analysis. Field campaign was organized from May to October 2017 for historical land occupational information via interview with land owners and farmers in twelve villages (Figure 1) at a rate of sixteen (16) respondents per village selected randomly based on the following criteria:

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proximity to original sampled forest (1 kilometer to forest site), land occupational time frame (minimum five year) after deforestation and spatial distributions in the same geomorphological unit, soil and climate conditions. This aims to calibrate and validate land use land cover maps and to characterize actual farming and cropping systems, their related effects on croplands and finally appraise the will of farmers to adopt integrated soil fertility, conservation, water management techniques in changing climate.

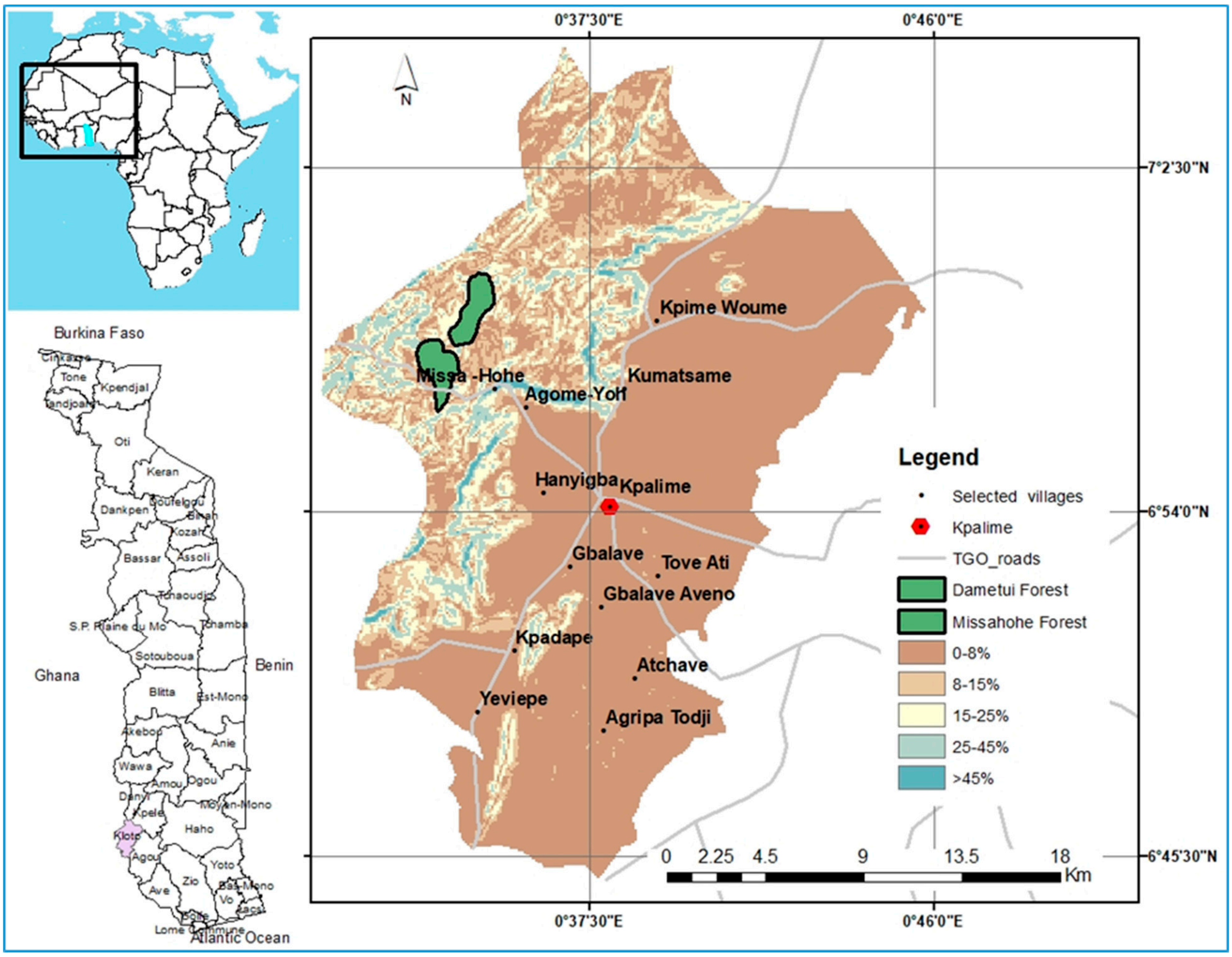

Figure 1. Kloto District with selected villages

Images were classified with 95 % accuracy with Kappa coefficient equal to 0.9 with 95% producer and user accuracy. Classified maps were used to derived the net changes graphs of 1985 – 2002, 2002 – 2017 and 1985 – 2017 using ArcGIS 10.3 raster calculator module. Descriptive statistics of net land use changes were performed at 95% confidence level using Microsoft Excel 2013. Questionnaire-based information was processed using SPHINX 4.5 software.

3. Results

3.1. Net change analysis

Results of the three land use land cover maps (Figure 2) and the statistical results (Table 2) depicted predominant decrease in forest areas from 42.78% in 1985 to 27.62 and 19.26 % in 2002 and 2017, respectively. In the meantime, areas under Cassava production and settlements increased up to 52.98 and 9.44 % in 2017.

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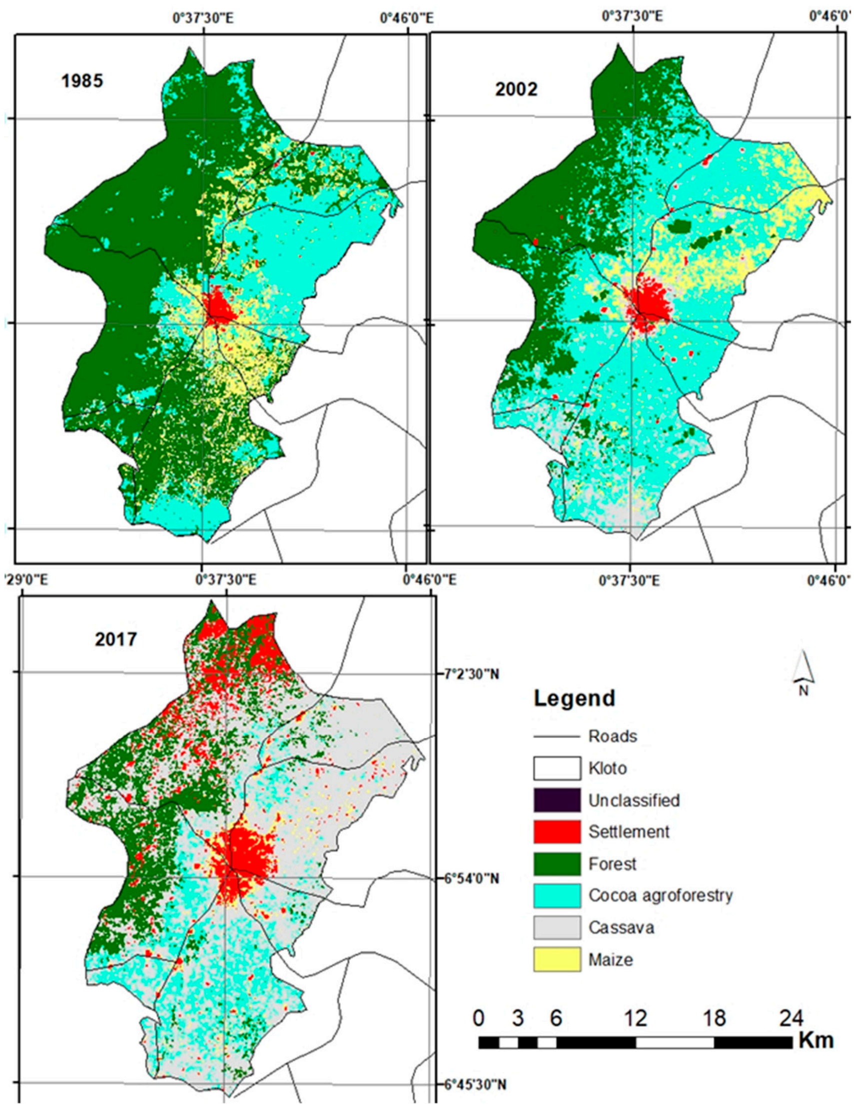

Figure 2. Historical changes in land use land cover from 1985 to 2017

Maize and cocoa agroforestry farming was less intense. The proportion of areas under maize cultivation decrease from 15.96 % in 1985 to 9.36 and 3 % in 2002 and 2017. meanwhile, cocoa agroforestry expanded during the first period (1985 – 2002) from 25.23 to 50.38 % and decreased considerably during the second period (2002 to 2017) from 50.38 to 15.18 %. The net change analysis (Figure 3) results revealed significant loss in forest cover by 23.6 % and surface areas under cultivation of cocoa agroforestry and maize by 12.99 and 10.1 % from 1985 to 2017 due to, intensive cassava cropping (38.78 %) and settlement expansion (7.84 %). Meanwhile, the loss of forest cover between 2017 and 2002 was marginal (8.36 %) compared to precedent periods (1985 – 2002) where, the loss was considerable (15.24 %).

Table 2. Dynamics in Land use land cover from 1985 to 2017

	1985		2002		2017	
	km²	%	km²	%	km²	%
Unclassified	0.54	0.10	0.75	0.14	0.72	0.14
Settlement	8.29	1.57	11.24	2.13	49.89	9.44
Cassava	75.03	14.37	54.76	10.37	279.85	52.98
Maize	84.46	15.96	49.42	9.36	15.86	3.00
Cocoa agroforestry	133.52	25.23	266.14	50.38	80.16	15.18
Forest	226.37	42.78	145.92	27.62	101.74	19.26
Total	528.21	100.00	528.23	100.00	528.22	100.00

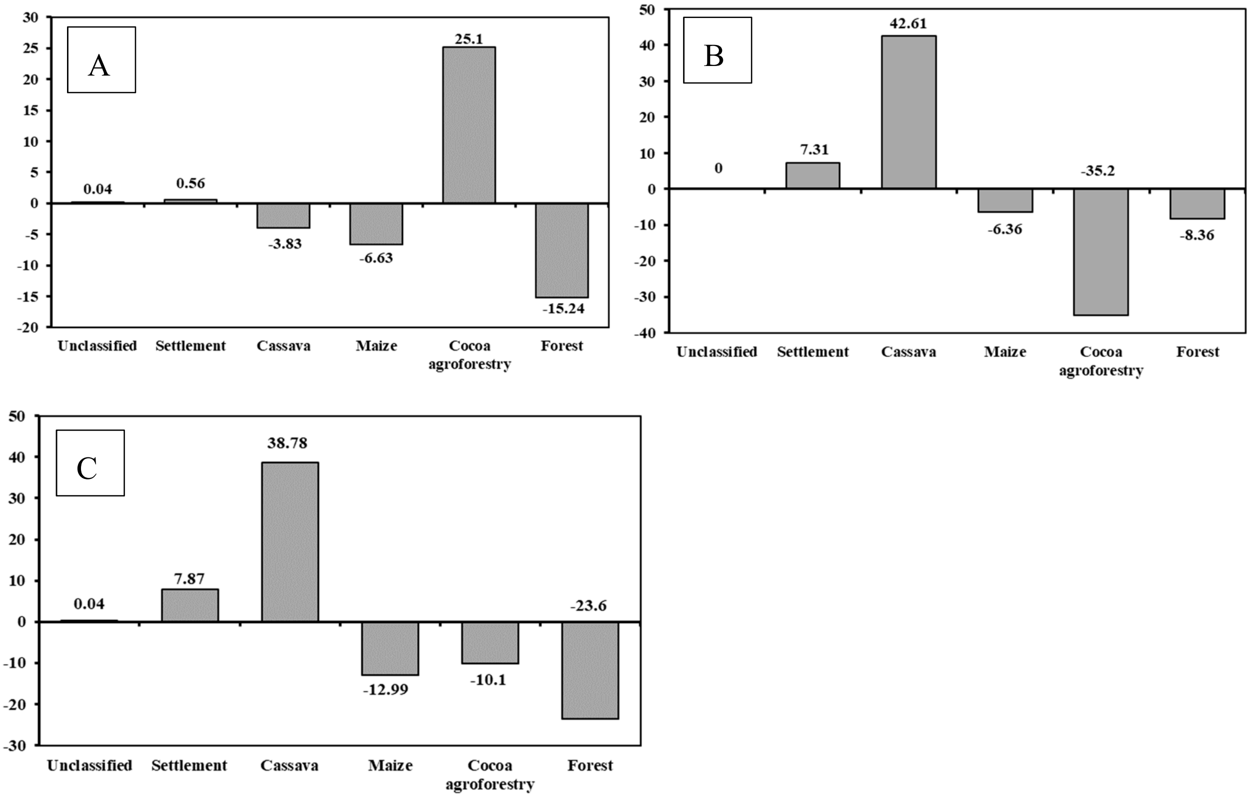

Figure 3. Net Land Use Land Cover Changes of 1985-2002 (A) - 2002 – 2017 (B) and 1985 – 2017 (C)

Similarly, between 1985 – 2017, cassava and maize lost 3.83 and 6.63% of their area of cultivations to the detriment of settlement expansions and cocoa agroforestry cultivations which, gained 0.56 and 25.1%, respectively (Figure 3). During the following period (2002 – 2017), settlement and cassava grew in size up to 7.31 and 42.61%, respectively, while, maize, cocoa agroforestry and forests depicted negative changes of 6.36, 35.2 and 8.36% in preceding order. Cocoa productions were low in some villages (e.g. Gbalave Volove; Kpime Woume). In the meantime, deforestation and forest degradation rates were also alarming in some areas, e.g. Kpime Woume, Atchave.

3.2. Current local farming and cropping systems in changing climate

Results from questionnaires data revealed an agricultural system largely dominated by men (104/120; 86.7 %). The age of the interviewed active farmers ranges between 19 and 56 years. Most of farmers have reached secondary (47.6%) and senior high (40 %) schools while, 11.7 % have primary degrees.

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Among the respondents, only 0.6 % have not gotten an official degree and none of them have earned a University degree. The test of knowledge on climate change and related effects on the agroecosystems showed that, most of respondents (63.3 %) have not heard or educated on climate change issues against a minority (36.7 %) whom affirmed to have some information on the subject matter. Majority of agricultural lands are threatened by erosion (67.5 %) followed by land degradation (56.7 %), soil fertility declining (32.5 %), declining in soil water holding capacity (11.7 %) and changes in soil texture (3.3 %). In terms of farming activities, Cassava, cocoa agroforestry (cocoa associated with plantain; trees and/or cassava at early stage) and maize are mainly produced at 34.2, 33.3 and 32.6 %, respectively under various cropping management systems. Land preparation and farms management are based on manual (75 %) and chemical tillage (70.8 %) followed by slash and burning (49.2%). 59.2 % are used to mixing cropping especially in cocoa production farming while 29.2 % and 11.7 % are practicing monoculture and rotational cropping, respectively. However, none of respondents uses fallow and/or agroforestry farming systems. Monoculture is predominant under maize (55 %) compared to cassava (32.5 %) while all farmers (100 %) practiced mixing cropping under cocoa agroforestry compared to cassava (45 %) and maize (32.5 %) farming.

3.3. Local willingness to adopt integrated soil and water conservation practices

Analysis of questionnaire data related to the adoption of improved agricultural practices and rainwater harvesting systems depicts favourable responses from respondents (Figure 4a and b). Soil mulching (35 %) is given more attention compared to composting (16.67 %) and contour tillage (5.83 %). The use of stone bounds is also useful for some farmers to the detriment of other selected practices (Figure 4a).

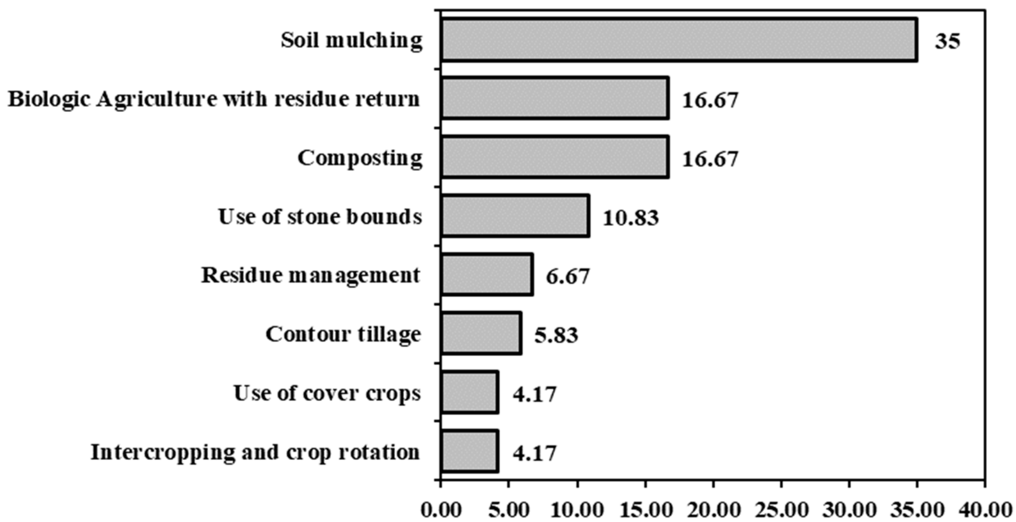

Figure 4a. Expected level of Adoption of Improved soil conservation practices

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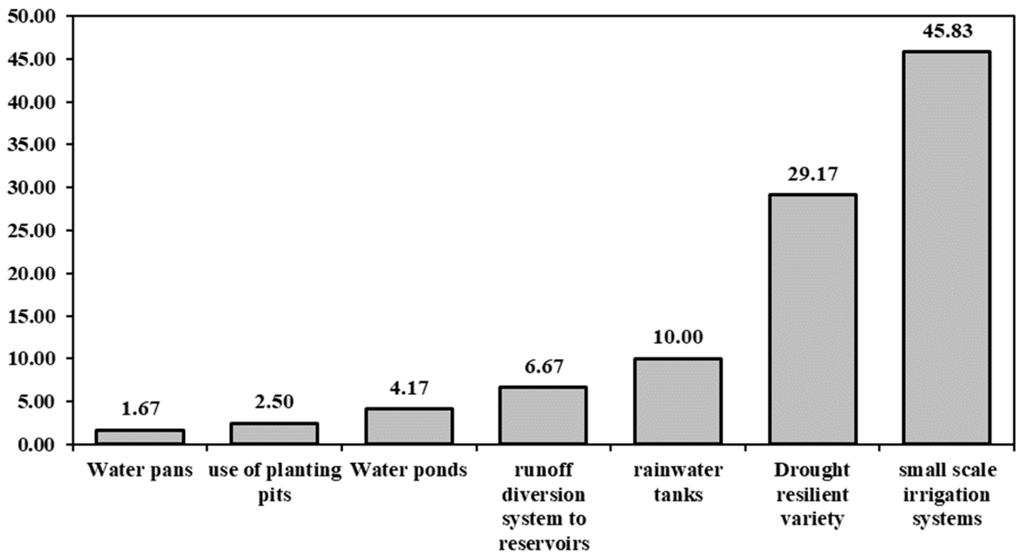

Figure 4b. Expected level of adoption of improved water management techniques

Regarding the integrated water resources and harvesting techniques, farmers will to pay more attention to small scale irrigation systems (cost effective drip irrigation) at 45.83 % (Figure 4b). In the meantime, relatively fair proportion intend to adopt drought resilient varieties (29.17%) to anticipate drought spells adverse. Additionally, respondents demonstrated strong willingness for adoption of other useful rainfall water harvesting systems such as: rainwater tanks (10%), construction of rainwater diversion systems to reservoirs (6.67%), use of planting pits (2.50%), water pans (1.67%) and ponds (4.17%).

4. Discussion

The net deforestation rate (Figure 2 and 3) is induced by both agricultural activities and settlement expansions. Survey analysis revealed the weaknesses of the agricultural systems in terms of farming and cropping systems that deteriorate farmlands. Indeed, in response to fertility decline and erosion problems, forests are cleared for fresh and stable lands for cropping to sustain food production. In this study, majority of agricultural lands are threatened by erosion (67.5%) followed by land degradation (56.7%), soil fertility declining (32.5%), declining in soil water holding capacity (11.7%) and changes in soil texture (3.3%) due to deliberate use of conventional practices (e.g. monoculture, chemical tillage) and non-adoption of climate smart practices in changing climatic conditions and exponential demographic rate. This study confirms existing findings on the role of agriculture in mitigating food insecurity and deforestation and forest degradation in changing climate (e.g. Kissinger et al., 2012; Tegegne et al., 2016). On the other hand, exponential shifting of maize production to cassava production and the overall expansion of cassava farming could be the results of croplands health status. Maize production required a certain minimum soil fertility conditions and when soil fertility declines, productivity is compromised. At this stage, these farmers find an alternative which consists of growing low inputs crop to restore soil fertility and benefit from crop leaves for food. On the other hand, Kloto farmers associate cassava to cocoa agroforestry production at infant stages of cocoa plantation with plantain and wild trees. Additionally, some farmers also practice association and/or rotational cropping on soils with low fertility capabilities. Callo-Concha et al. (2013) presented major traits of farming and cropping systems in West Africa in changing climate. Results concluded the weaknesses of the systems vis a vis to technical, environmental and socio political constraints. Therefore, the formulation of strategies must be based on the assessment and understanding of the farming systems at local level through participatory approach with stakeholders. As African soils are poor in organic matter, improved soil fertility, erosion control and water management techniques are fundamental to guaranty a perfect cohabitation of agriculture and forests in developing countries. This study underlines the actual poor agricultural systems and

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presents the expected adoption level of improved practices to the benefit of food security, forest sustainability and climate change mitigation.

5. Conclusions and Recommendations

Better understanding of west African farming, cropping systems and population dynamics is a prerequisite to develop measures and technologies in promoting perfect cohabitation of agriculture and forests sustainability schemes. In this light, this study combined remote sensing and survey data to first analyse the historical net changes in land use and land cover and assess and understand the reasons of deforestation and forest degradation in Kloto district (Togo, West Africa). This approach enables to better comprehend proximate drivers of deforestation and forest degradation by perceiving the weaknesses of the existing farming and cropping systems, major reasons of shifting from one farming systems to the another and more importantly, reasons of deliberate conversion of native forests and the willingness of farmers to adopt improved soil conservation and water management practices. Simply put, the participatory approach shows that pressure on croplands with actual farming and cropping systems entails severe land degradation. To circumvent these situations, farmers are obliged to shift either from cereal mono-cropping (e.g. maize) to root crops (e.g. cassava) as alternative to restore degraded soils or clear existing adjacent forests, in search for more stable and healthy soils to sustain food productions. Accordingly, this study paves way for policy formulation towards appropriate cropland land managements, land use planning strategies and capacity building of smallholders. These are of utmost relevance to slow down forests shrinking while sustaining foods and improving socio economic livelihoods conditions of the most vulnerable layers residing in poorest and remote communities of Kloto district (Togo, West Africa) whom leave and depend on agriculture and forests products. Joint efforts from governments, civil societies with farmer's collaborations to evaluate actual and emerging problems in the agricultural sector and identify, establish and implement sustainable solutions to promote agro and forest ecosystems through the following:

- Most suitable Governance principles: Transparency, fair accountability and inclusive Sustainable Agricultural Land Management (SALMP) and advanced crop breeding projects design, monitoring and management.

- Gender consideration in political decisions

Women are earful to new technologies and have the ability to implement them adequately. In our societies due to cultural barriers, this right. Accordingly, there is a need to reinforce women ability to get access the lands and revise land tenure and ownership systems through equity in land sharing. From climate change side, women are the most vulnerable entity for their various attributions to supply food and provide insurance for the whole family in case of climatic adverse. Front this fore front, their financial stability and strong technical capacity building is a prerequisite to the success of agro and forest ecosystem sustainable management.

- Capacity building of public workers in Agricultural Research Institutes, Extension Services and technology transfer.

Agricultural Research Institutes, Universities and Extension Services must collaborate, work hand-in-hand with local NGO's for proper dissemination and propagation of improved practices in exposed and targeted zones.

Author Contributions: YSK, WAA, JMS and TG designed the project; YSK conducted the fieldwork and performed the data collection, analysis and manuscript draft. BD, AKA, WAA and JMS appended their valuable comments on the manuscript.

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Conflicts of Interest: Authors declare that they have no competing interests.

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