WIDER Working Paper No. 2013/110

Trends and patterns of land use change and international aid in sub-Saharan Africa

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October 2013

Abstract

The sub-Saharan Africa region recorded the fastest conversion of forest land to agriculture in the past 20 years. The region also has the widest yield gap and together with Latin America and Caribbean has the largest unused arable land. However, there are wide variations across countries and this offers valuable lessons on the drivers of agricultural intensification and land use dynamics. This study shows only few countries experienced a decrease in cropland extent. Additionally, few countries with low agricultural potential have shown higher actual maize yield while others with high potential have shown lower actual yield.

Consistent with Boserupian theory, our analysis of the drivers of cropland extent show public expenditure on agricultural research and development and population density both have an inverted U non-linear relationship with cropland extent. Similarly, international aid first…/

Keywords: croplands, aid, agricultural intensification, markets, land rights, governance
JEL classification: F18, Q15, Q16, Q18

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This study has been prepared within the UNU-WIDER project 'ReCom–Foreign Aid: Research and Communication', directed by Tony Addison and Finn Tarp.

UNU-WIDER gratefully acknowledges specific programme contributions from the governments of Denmark (Ministry of Foreign Affairs, Danida) and Sweden (Swedish International Development Cooperation Agency—Sida) for ReCom. UNU-WIDER also gratefully acknowledges core financial support to its work programme from the governments of Denmark, Finland, Sweden, and the United Kingdom.

ISSN 1798-7237 ISBN 978-92-9230-687-8

… increases the extent of cropland area but reaches a threshold beyond which it decreases cropland area. The results suggest that growth in population and more investments in research and development will spur more agricultural intensification on the region. The results from the interaction effects of rural population and poverty show that poverty in densely populated rural areas is associated with greater cropland expansion. Agricultural exports, agricultural potential and land tenure security all reduce cropland extent. Access to markets increases cropland expansion suggesting that high returns and high demand for agricultural products in high market access could lead to severe deforestation. The results have important implications on the policies which should be used to enhance agricultural intensification while protecting forests and other natural resources which could be compromised with cropland expansion. The results also have important implications on strategies for exploiting the region's large potential to produce its food for the rest of the world. The multiple factors with significant impacts on cropland extent also underscore the complex crop intensification and land conversion relationship, which require an equally complex approach to achieve sustainable agricultural intensification.

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Typescript prepared by Janis Vehmaan-Kreula at UNU-WIDER.

1 Introduction and motivation of the study

International aid to sub-Saharan Africa (SSA) has been seen by some scholars as stimulating economic growth (e.g. Clemens et al. 2004), while others have viewed it as being driven by donor, political, and strategic objectives with limited or no impact on economic growth of recipient countries (e.g. de Mesquita and Smith 2009; Berthélemy 2006). Given the recent renewed interest in international land acquisition and investment in SSA, an interesting question is to examine the role played by international aid on land use. The demographic and land-based sector performance in SSA also raises attention to re-examining the impact of international aid on land use. Population growth in SSA is the fastest—leading to the fastest loss of arable land per capita in the world (Nkonya et al. 2012).[1] SSA also accounted for 66 per cent of the 234.5 million hectares reported to have been acquired by foreign investors between 2000-11 (Anseeuw et al. 2012). In the last two decades, SSA also experienced the fastest deforestation in the world (FAOSTAT 2012). During the same period, forest density (tree density per hectare) in the world increased significantly but the increase in SSA was only modest (Rautiainen et al. 2011).

Agriculture is the leading form of land use change in SSA (Foley et al. 2011) and development of the sector has remained the lowest in many aspects in the world. This study examines the agricultural land change and its drivers in SSA over a period of 30 years beginning 1977-2007, and how international aid has affected such changes. To set the stage and motivate this study, the following section examines the pattern of international aid to SSA and its potential impact. This is followed by a review of the change of extent of cropland area in SSA. A theoretical framework is then discussed—followed by the empirical model used. Data and descriptive statistics are then discussed followed by econometrics results. The last section of the paper concludes and draws policy implications.

2 International aid to SSA and its potential impact on land use

International aid to land-based sectors can change land use in a number of channels. The donor direct budget support could influence protected area and zoning policies strategies, which in turn could limit deforestation and other land use and land cover changes. For example, budget support for environment, biodiversity and forestry could enhance government strategies to protect forests and terrestrial ecosystems. Additionally, international aid targeted to agricultural research and development (R&D) could enhance agricultural productivity and in turn reduce cropland expansion. For example, international donors have remained the major funders of agricultural R&D in SSA (Beintema and Stads 2011) and that about 30 per cent of the Organisation for Economic Co-operation and Development (OECD) disbursement to agriculture in SSA in 2007 went to agricultural R&D (Hearn et al. 2009).

The Paris Declaration—whose objective is to increase aid effectiveness (OECD 2008)[2] gave recipient countries more latitude to allocate aid to national development programmes

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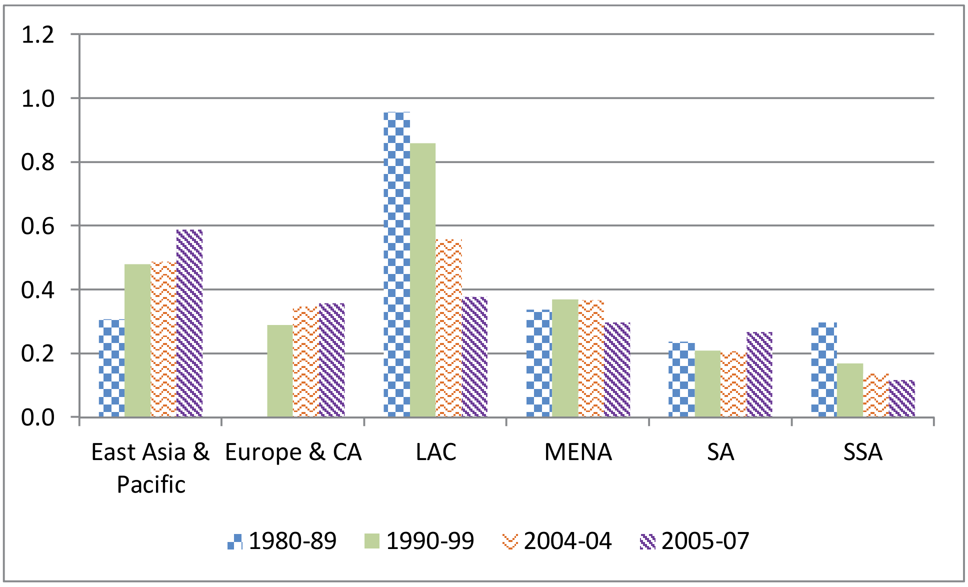
1 SSA arable land per capita decreases by $76m^2$ per year compared to $46m^2$/year for Asia, the region experiencing the second fastest loss of arable land (Nkonya et al. 2012).

2 The Paris Declaration worked under four mutually enhancing principles: increase ownership of recipient countries of development efforts, alignment of support to recipient country development programmes,

designed by recipient countries. This was especially the case for donor funding directly supporting recipient country government budgets. The Paris Declaration objectives are well-intentioned and have been viewed to have increased aid effectiveness (OECD 2008) but it has the potential of perpetuating the limited and decreasing investment in agriculture, which SSA countries have experienced in the past 30 years (Cook 2009; Figure 1).

Figure 1: Trend of agricultural orientation index (AOI) in SSA compared to other regions



Note: (i) $\text{AOI} = \frac{\text{Share of agriculture in total government expenditure}}{\text{share of agriculture in total GDP}}$

(ii) LAC = Latin America and Caribbean; MENA=Middle East and North Africa; SA=South Asia, CA=Central Asia.

Source: FAO (2012).

ODA total support and support to agriculture, water and the environment both decreased following the Paris Declaration in 2005 but increased beginning 2007 (Figure 2) largely due to renewed interest of high income countries and transnational companies to invest in agriculture following the food price spike and increasing demand for bioenergy (HLPE 2011; Figure 3). However, ODA support to agriculture as share of total support to all sectors has not fully recovered to its level attained in the 1980s (Figure 4).

The major question in this paper is to examine the influence of international aid on land use. Particularly, we examine how aid trends observed in Figure 2 and Figure 3 is related to land use change in the SSA recipient countries.

The section below discusses the land use change patterns—with focus on cropland extent—which drives much of land use change. The section then discusses the relationship of land use change and international aid.

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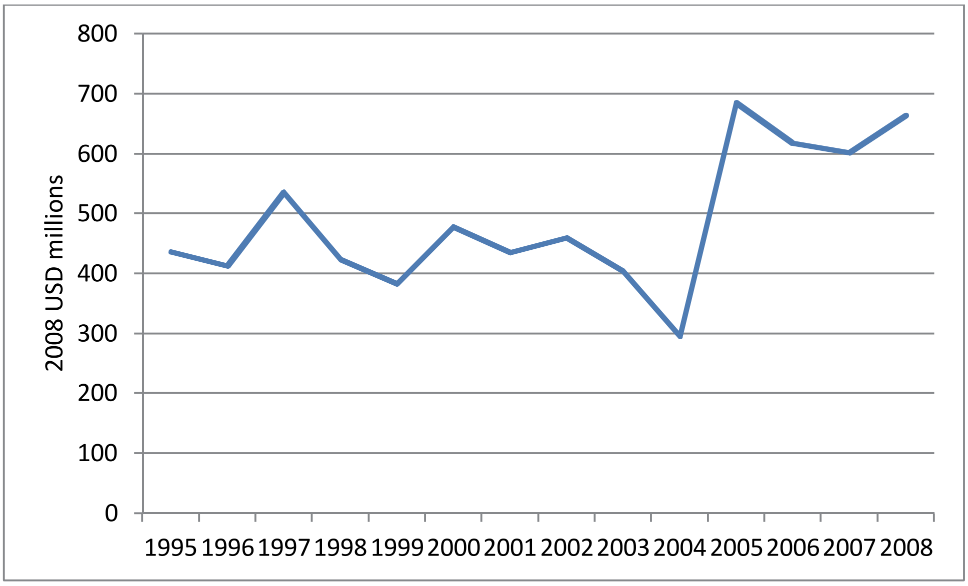
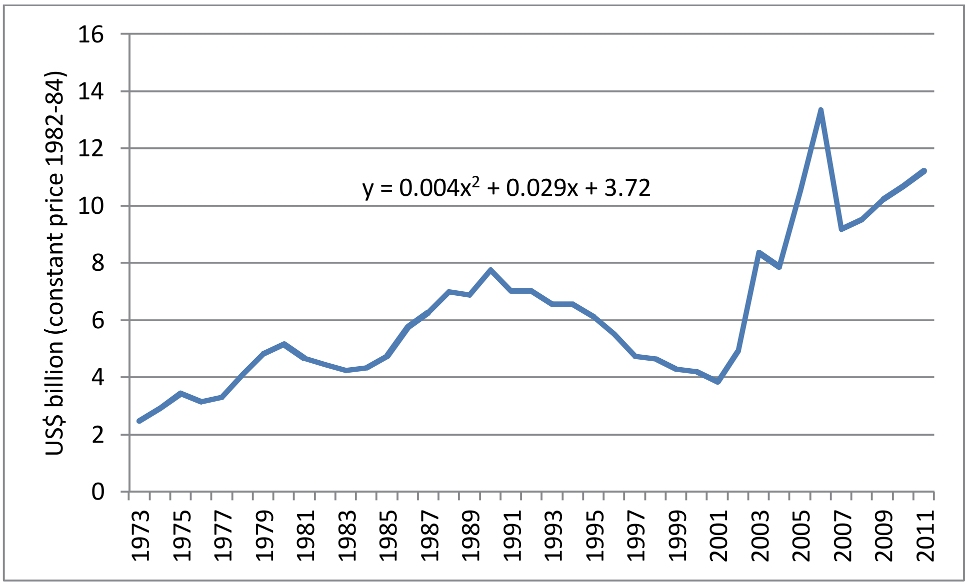
harmonization of donor support, effectively managing resources for development and mutual accountability of donors and recipient countries to development results (OECD 2008).

Figure 2: DAC total support to agriculture, water and environment



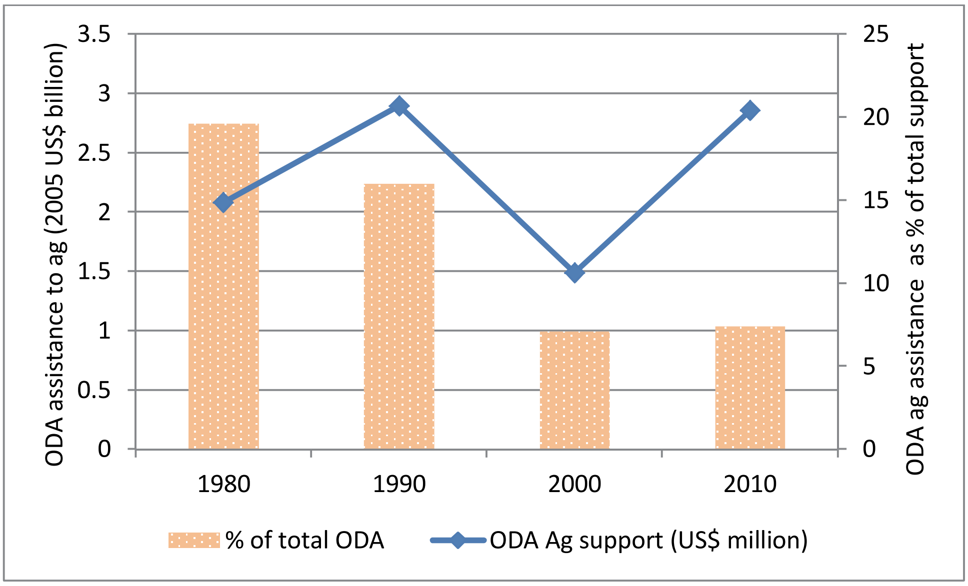
Source: DAC.

Figure 3: ODA disbursement trend to SSA



Source: Extracted from http://stats.oecd.org/qwids/

Figure 4: Trend of ODA assistance to agriculture in SSA

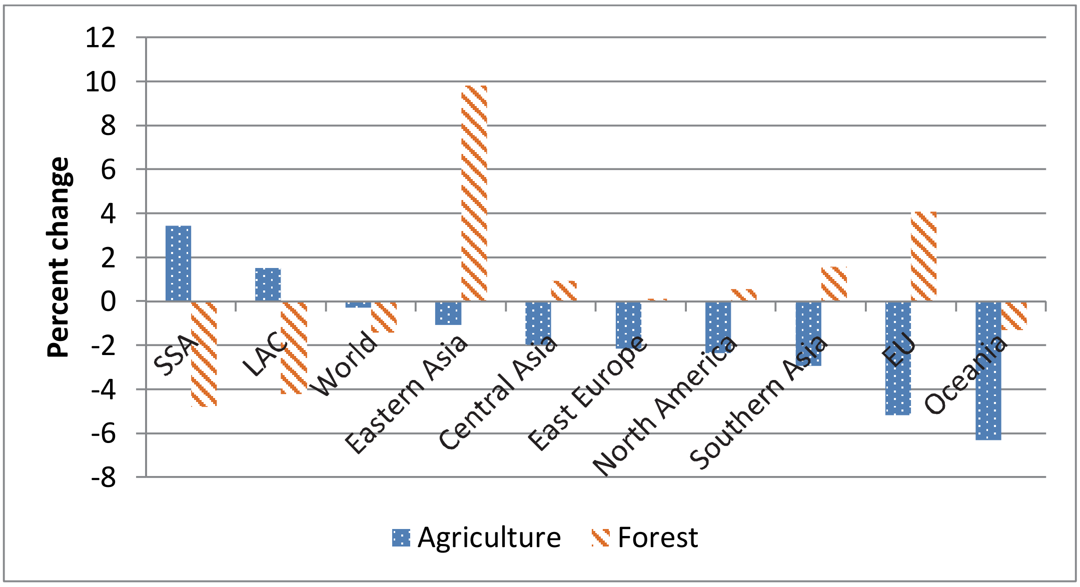


Source: FAO (2012).

3 Review of change of land use change and international aid in SSA

Even though rates of agricultural expansion decreased by 0.3 per cent globally, extent of cropland increased by 4 per cent in SSA between 1992-2009—the largest increase in the world (FAOSTAT 2012; Foley et al. 2011). Consequently SSA experienced the highest deforestation rate in the world (Figure 5).

Figure 5: Change of agricultural and forest area, 1992-2009



Note: Change computed as follows $\frac{y_2 - y_1}{y_1} * 100$

Where y_1 = average area 1992-2000 and y_2 = average area 2001-2009

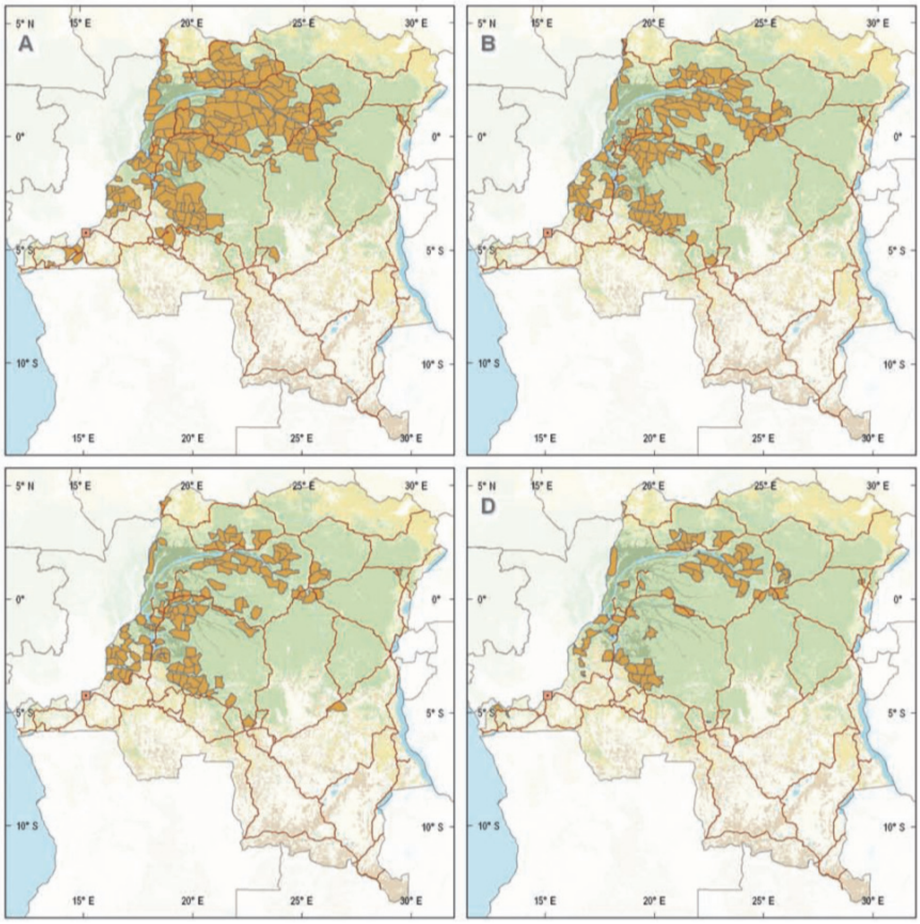
LAC = Latin American Countries; SSA = sub-Saharan Africa; EU = European Union

Source: FAOSTAT data.

Average increase in cropland area between 1973-83 as baseline and 1997-2007 as endline shows a 23 per cent increase in cropland area, the leading cause behind SSA's rapid cropland expansion is the low crop yield and subsequently wide yield gap—the difference between potential actual yield. SSA had the widest yield gap of maize, rice and wheat in the world (Nkonya et al. 2012) and agriculture contributed only 38 per cent of the increase in agricultural production between 1961-2005 compared to the global contribution of 77 per cent during the same period (Figure 6). The small contribution of yield increase to total production is due to a number of reasons including poor market conditions that provide incentives for farmers to invest more in increasing productivity.

Figure 6: Changes in the surface area allocated to timber concessions, DRC

	A	B	C	D
Year	2000	2003	2007	2009
Area (million ha)	42	25	26	12



Source: World Resources Institute. Available from: www.wri.org/publication/interactive-forest-atlas-democratic-republic-of-congo

Some countries saw a decline in the cropland area due to growth of non-agricultural sectors (Botswana, Equatorial Guinea, Congo, Mauritius, Seychelles, and Reunion). However, for some countries, the decrease in cropland land could be due to poor data rather than actual decrease. For example, Ethiopia showed a 10 per cent decrease. Given that the country's rural population increased, such data hardly reflect the reality on the round. For the Democratic Republic of Congo (DRC), the slight decrease in cropland could be due to the insecurity which prevailed in much of the endline period. Insecurity has also influenced dynamics of forest cover in DRC. For example, Mertens et al. (2010) showed that area under forest concessions decreased from 42 million ha in 2000 to only 12 million ha in 2009.[3]

In Mali and Mauritania, cropland area more than doubled (Table 1). Again such dramatic increase reflects data quality problems rather than actual increase in cropland area. Despite these weaknesses, FAOSTAT datasets have been widely used due to their easy availability and long-term historical data.

Table 1: Countries which experienced a decrease and large increase in cropland

Country	Baseline, 1973-83	Endline, 1997-2007	% change
	Million ha		
Countries with declining cropland area[a]			
Botswana	0.40	0.24	-41
Guinea	3.56	3.12	-12
Ethiopia PDR[b]	13.63	12.23	-10
Senegal	3.21	3.08	-4
Equatorial Guinea	0.23	0.22	-3
Congo	0.55	0.54	-1
DRC	7.55	7.49	-0.4
Countries with >30% increase in cropland areaa			
Kenya	4.22	5.54	31
Uganda	5.61	7.73	38
Sudan (former)[b]	12.36	17.53	42
Niger	9.96	14.15	42
Malawi	2.10	3.01	43
Mozambique	3.12	4.56	46
Zimbabwe	2.60	3.80	46
Gambia	0.17	0.28	63
Côte d'Ivoire	4.08	6.76	66
Burkina Faso	2.68	4.51	69
Guinea-Bissau	0.30	0.52	70
Benin	1.53	2.73	79
Ghana	3.54	6.34	79
Sierra Leone	0.51	0.98	93
Mauritania	0.22	0.45	106
Mali	2.01	5.17	157
SSA	163.97	202.36	23

Notes: [a] Excludes small islands, [b] Sudan (former) includes both Sudan and South Sudan and Ethiopia PDR includes Ethiopia & Eritrea.

Source: FAOSTAT data.

3 See Box 1.

Box 1: DRC low deforestation mystery

DRC accounts for about 35 per cent of the carbon stock in SSA (Baccini et al. 2008) and 24 per cent of the renewable freshwater resources (AQUASTAT 2013). DRC is among the seven countries in the world that account for half of the remaining 1.8 billion hectares of suitable land (Bruinsma 2009). Despite these abundant resources, DRC—with a gross national income (GNI) per capita of $319 in 2012—had the lowest human development index in the world (UNDP 2013).[4] In 2013, about 71 per cent of the population lived below the national poverty line (UNDP 2013). The 2011 Global Hunger Index placed DRC at the lowest level in the world (von Grebmer et al. 2011). Additionally, a global ranking of government effectiveness (Kaufmann et al. 2010), a government's capacity to implement policies with independence from political pressures and with respect to the rule of law, put the DRC's government as the fourth least-effective in the world (Kaufmann et al. 2009).

One would expect that in such an environment, deforestation and other forms of land degradation would be severe. However, lack of infrastructure has seriously reduced logging and other forest harvesting activities. DRC had the lowest Logistics Performance Index (quality of trade and transport-related infrastructure)[5] in the world in 2012. The civil war in the country has also limited both the commercial logging and farming activities. The area covered by legal concessions has dramatically declined since 2000, when 42 million hectares were allocated (Figure 6). The deforestation rate in DRC (2.6 per cent) is smaller than half of the SSA average (5.6 per cent).

The main drivers of deforestation are informal logging for timber for local or regional use, charcoal production and land clearing by shifting farmers (Tollens 2010). Commercial logging only contribute a small share of deforestation (Ibid).

Where has agriculture been expanding?

Agriculture can only expand in an area that provides the ecological requirements of crops or livestock. FAO's Global Agro-Ecological Zone (GAEZ) defines suitable land as land with soil, terrain and climate characteristics which meet the crop production requirements with specified input levels (Fischer et al. 2002). Using Landsat data and groundtruthing surveys covering 47 sites in SSA, Gibbs et al. (2010) observed that in about 60 per cent of new agricultural land replaced intact forests, and another 35 per cent replaced disturbed forests and only 5 per cent came from shrublands (Figure 7). The cropland expansion pattern differs across regions. In East Africa and Central Africa, 50 per cent and 70 per cent respectively of cropland land replaced intact forest.

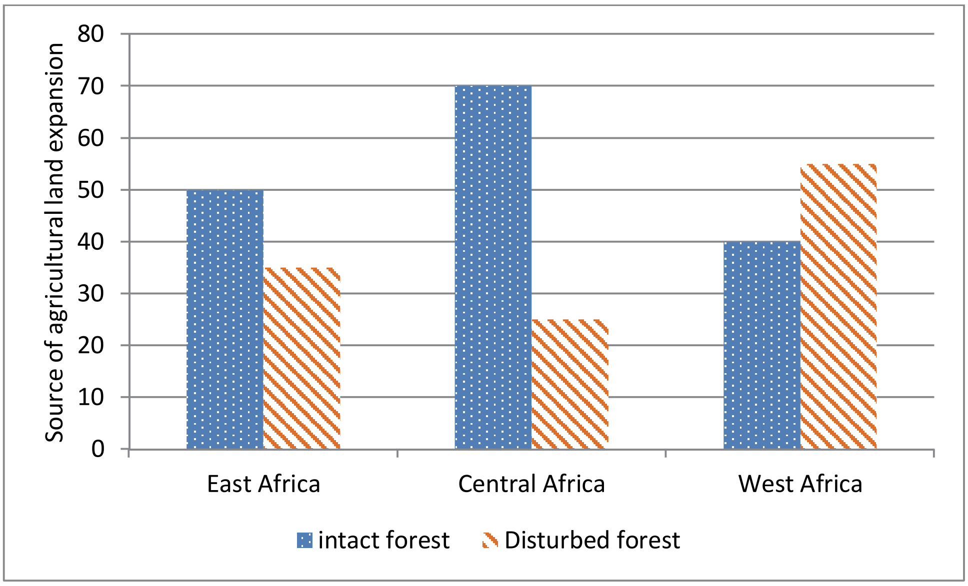
SSA and the Latin American and Caribbean (LAC) regions each account for 25 per cent of the global suitable land (Figure 8). About 90 per cent of the remaining 1.8 billion ha of global arable land in developing countries is in LAC and SSA (Bruinsma 2009). Three of the seven countries, which account for half of the remaining suitable land in the world, are in SSA (Angola, Democratic Republic of Congo and Sudan) (Ibid).[6]

[4] Niger also had the same HDI (0.304) but its mean number of schooling years was lower than that of DRC (UNDP 2013).

[5] http://data.worldbank.org/indicator/LP.LPI.INFR.XQ/

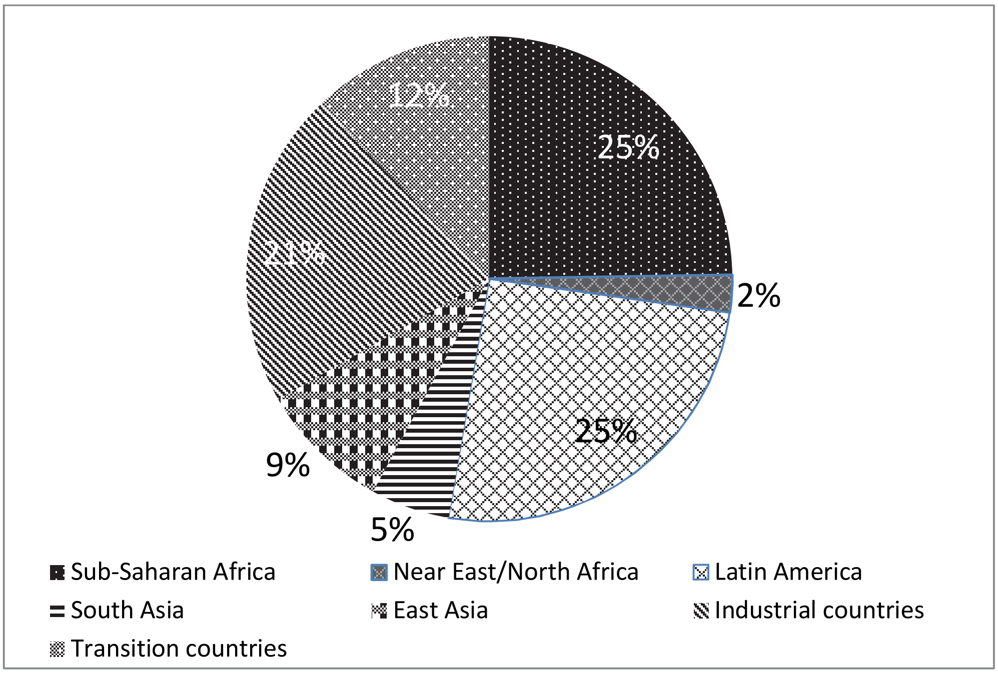
[6] Others are Brazil, Argentina, Colombia and Bolivia.

Figure 7: Source of agricultural land expansion in Africa, 1980s-2000



Source: Based on Gibbs et al. (2010).

Figure 8: Contribution of regions to global suitable land



Source: Based on Bruinsma (2009).

It is also in countries with large arable land area where there is still a large gap between agricultural yield potential and actual yield. Such a large gap provides the potential for increasing agricultural production to cater for the increasing demand for agricultural products. However, closing the wide agricultural productivity gap requires significant investment to address constraints which lead to the low agricultural productivity.

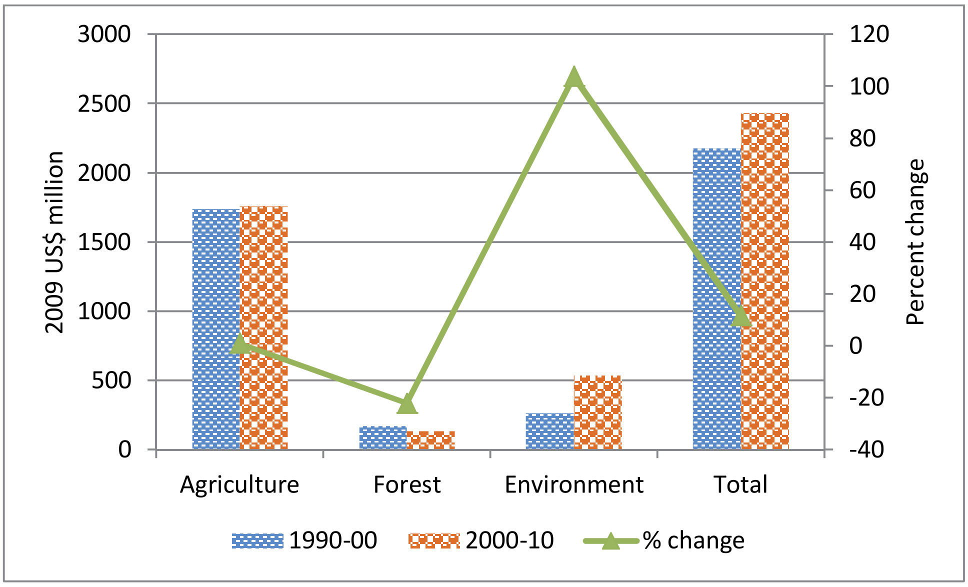
Countries which invest in agricultural R&D achieve greater land productivity and are more likely to achieve sustainable land management (SLM) than those which spend less (Lobell et al. 2009). A recent study has shown that agricultural R&D investment in SSA increased by 20 per cent in 2001-2008 (Beintema and Stads 2011). However, the growth was concentrated in only eight countries (Nigeria, South Africa, Kenya, Ghana, Uganda, Tanzania, Ethiopia, and Sudan), which accounted for 70 per cent of the region's increase in public agricultural R&D expenditure and 64 per cent of all researchers increase during the same period (Ibid). In all countries, research on crops accounted for the largest share of staff time, underscoring the importance of crops in the region.

4 Relationship of land use change and international aid

Donor support of agriculture, forest and the environment affect land use change directly. For example, the ministries of environment in many SSA countries are responsible for enforcing laws and regulations on protected areas (PA). Ministries of environment and agriculture in SSA receive a large portion of their budgets from donors (Emerton et al. 2006; Wittemyer et al. 2008; Lambert 2006). For example, the Global Environment facility (GEF) invested about US$2 billion in protected area (PA) programmes in Africa and Latin America in 1991-2006 (GEF 2006). Likewise, donors have contributed a large share of SSA's public expenditure to agricultural on research and development, an investment which has led to significant increase in agricultural productivity and poverty reduction (FAO 2012). Total donor support to the three land-based sectors (environment, agriculture and forest) increased by only about 12 per cent in 2001-10 compared to its level in 1990-2000 (Figure 9). Donor support to environment accounted for the largest increase while agriculture accounted for the largest share of aid (more than 70 per cent of total commitment for both 1990-2000 and 2001-10 periods). Total donor support to forestry in 2001-10 declined slightly compared to its level in 1990-2000. The total donor support to agriculture—the main driver of land use change (Lambin and Meyfroidt 2011; Gibbs et al. 2010)—increased only slightly. However, donor support to the agricultural sector as per cent of GDP declined from 1.6 per cent in 1990 to 0.9 per cent in 2010 (Figure 10). Likewise, ODA support to agriculture as share of total support has declined since 1980 (Figure 10). ODA support to PA as per cent of total GDP in SSA has been increasing over the past two decades.

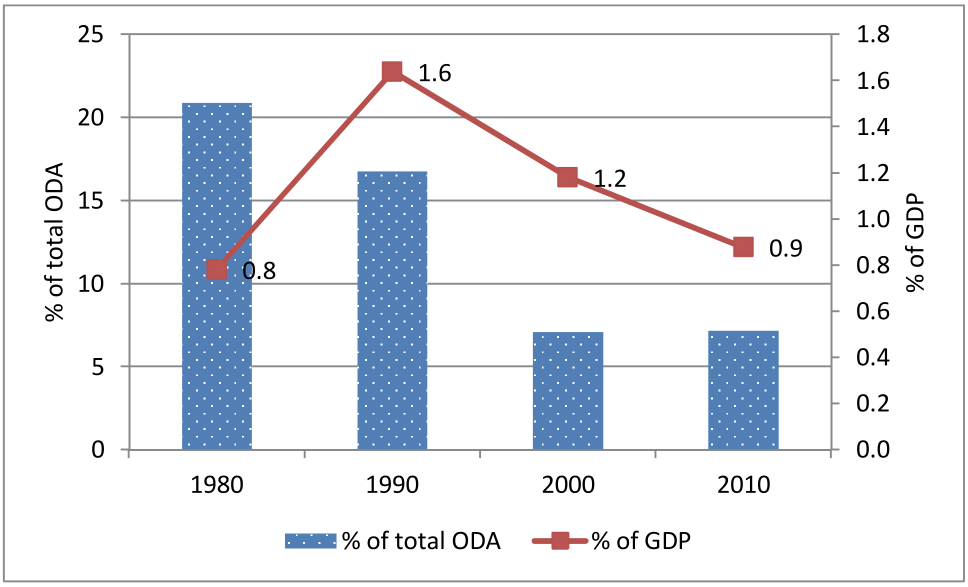
There was a rapid increase of donor support to environment after the Earth summit in Rio de Janeiro in 1992 (Figure 11). While the area under PA in SSA increased by only 4 per cent from an average of 2.72 km^2 million in 1990-2000 to 2.83 km^2 million in 2000-10, total aid to environment, under which PA is classified by ODA, more than doubled during the same period (Figure 11). The targeting of the donor support to environmental issues was also generally good. A study by Wittemyer et al. (2008) shows that donor funding was well-targeted to the value of biodiversity and anthropogenic pressure—as expected. The same study however showed that PA donor funding in developing countries attracted settlement around PAs and eventually led to deforestation around PAs though it reduced encroachment of cropland into protected areas (Wittemyer et al. 2008). Hartley et al. (2007) also showed that EU funding was well-targeted to PA with high biodiversity value and anthropogenic pressure. However, the study was unable to establish the impact of the EU funding on PA since such impact can only be established long-term data (Ibid).

Figure 9: Change in ODA and non-ODA support to agriculture, forestry and environment, 1990-2000 to 2001-10



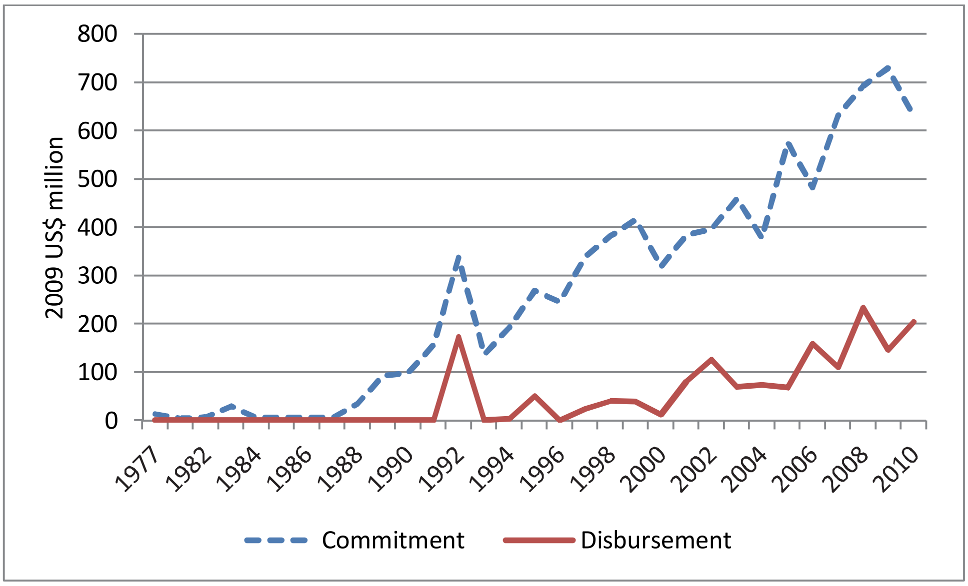
Source: Based on Tierney et al. (2011).

Figure 10: Trend of ODA support to agriculture in SSA



Sources: ODA support (OECD 2012); GDP (IMF 2013).

Figure 11: Trend of donor support from ODA and Non-ODA donors to environment in SSA



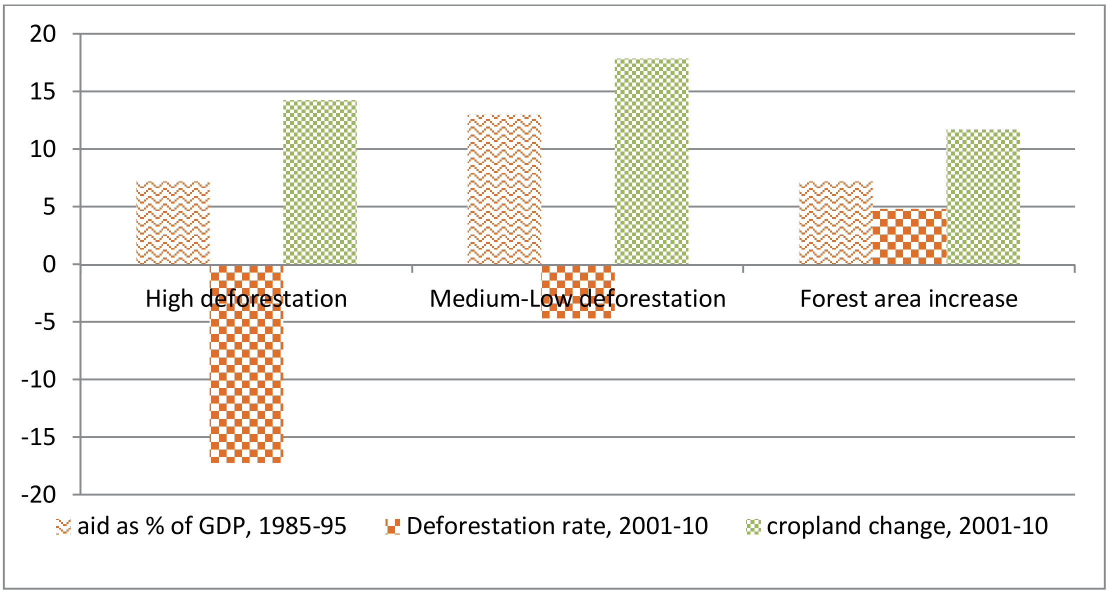
Source: Based on Tierney et al. (2011).

We look at funding of the three land-based sectors with an objective of determining their relationship and potential impact of donor funding on land use change. Given that the donor funding will take some time to have an impact on land use change, we use a 10 year (1985-95) average of donor support as per cent of GDP and relate it with corresponding change in land use change in 2001-10.

Figure 12 shows that countries with medium to low deforestation rates received the largest ODA disbursement as per cent of GDP but also experienced the largest cropland expansion.

An examination of the donor funding to agricultural research and development could shed more light on land cropland expansion. Theory predicts that increased productivity could lead to intensification and eventually decrease in agricultural extent (Boserup 1965). This could happen if supply is elastic (Bourlaug 2007). However, empirical evidence shows that both agricultural yield and extent could increase simultaneously (Rudel et al. 2009b). For example, between 1990-2005, only North America and Central America and Caribbean saw an increase in crop yield associated with a fall in cropland area (Figure 13). Simultaneous increase in crop yield and cropland expansion could be driven by a host of factors including international trade, incentives to exploit higher land productivity and others. Akramov (2012) also observed that countries with democratic governance—political rights and civil liberties—were more likely to receive aid. Overall, recipient needs (Fleck and Kilby 2010), and donor strategic, political and economic interests are among the major determinants of aid allocation (de Mesquita and Smith 2009; Berthélemy 2006). With the exception of Angola, Kenya, and Mauritius, countries which experienced medium to low deforestation are characterized by a small per capita GDP (see Appendix 1) suggesting that a reasonably small ODA support could account for a large per cent to GDP. Our analysis on drivers of agricultural land area will exploit this question further. To set the stage for such analysis, the next section discusses the theory of land use change.

Figure 12: ODA aid as per cent of GDP and its relationship with deforestation and cropland change in SSA

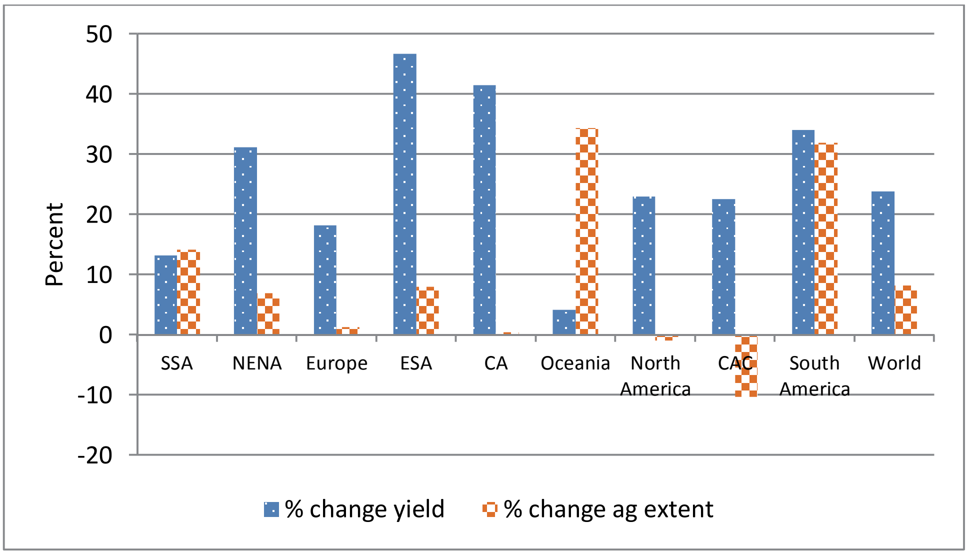


Notes: (i) Averages exclude small island nations

(ii) Forest and cropland trend $=\left(\frac{a_2-a_1}{a_1}\right)x100$, where a_1 = average area in 1986-95 and a_2 = average area, 2001-10.

Sources: FAOSTAT (deforestation and cropland area), ODA (aid) and World Bank (GDP).

Figure 13: Change in crop yield cropland area across regions, 1990-2005



Notes: CA = Central Asia, ESA = East and South Asia, CAC = Central America and Caribbean, NENA = Near East and North Africa; SSA = sub-Saharan Africa

Based on 10 major crops: Maize, rice, soybeans, wheat, banana, cocoa, coffee, sugarcane, potatoes and cotton.

Source: Based on Rudel et al. (2009a).

5 Theoretical framework of the drivers of cropland change

Theory posits that population growth induces agricultural intensification (Boserup 1965). Intensification is a result of growing population which leads to land scarcity relative to available labour. Consequently, the value of land increases and land users intensify to get the maximum returns from land. However the Boserupian theory has not held in many poor countries, such that population density has been associated with land degradation and decreasing agricultural productivity (e.g. Grepperud 1996; Scherr 2000; Mäler 1997).This means the Boserupian theory will hold only if other conditions examined below are met. Tiffen et al. (1994) observed in Machakos Kenya greater land investment to prevent land degradation where population density also increased. Such intensification occurred because prices, markets and other socio-economic conditions favoured land investment (Mortimore and Harris 2005; Boyd and Slaymaker 2000).

Related to the Boserupian theory is the evolutionary land rights theory (ELRT), which is also related to population density and land scarcity. The ELRT shows that as land scarcity increases, land users will demand land tenure security (Platteau 2000). Studies have also shown that secure tenure rights are associated with greater land investment. For example, de Soto (2000) attributes much of low land investment in developing countries to lack of tenure security. Goldstein and Udry (2008) also note that tenure security encourages long-term investment. However, other studies have also shown that investment in lands held under customary tenure—which is assumed to have insecure security—were comparable or better than investment in lands (Deininger and Jin 2003; Toulmin and Quan 2000). This suggests that land holders could fill having secure tenure even when they do not have formal titles. These results, suggest that land users perception of land tenure security is more important than formal titles. However, this does not mean that customary tenure security is secure. For example, recent studies have shown that land grabbing was more pronounced in areas with poor land tenure security (RRI 2013; HLPE 2011).

Poor governance could lead to weak or lack of protection of forests and other pristine ecosystems—leading to rapid expansion of agricultural land into forested areas and other common resources (Wade 1987; Ostrom 1990; Baland and Platteau 1996; Agrawal 2001). However agricultural expansion could also lead to deforestation even in countries with strong governance. For example, the Brazilian Amazon occupation was largely determined by government efforts to colonize the forested area (Fearnside 2002; Peres 2001).

Household level characteristics of land users affect change of extent of cropland. Farmers with a higher level of education are likely to have non-farm activities and therefore could depend less on farming (Haggblade et al. 2007; Chenery and Syrquin 1975). Likewise, empirical evidence has shown access to credit increases the probability of farmers to be engaged in non-farm activities (e.g. see Haggblade et al. (2007) and therefore less dependence on farming.

Access to markets is an important factor of cropland intensification or expansion. Controlling for population density, land institutions and other factors, access to markets lowers transactions costs for both agricultural outputs and inputs and this could lead to intensification (Binswanger and McIntire 1987) and slower expansion of cropland extent at household level. However, greater profits for areas with better market access could lead to area expansion and even land degradation (McCarthy et al. 2001; Benin and Pender 2001). This also shows that the impact of access to markets is context-specific.

According to the environmental Kuznet curve and forest transition, economic development will first lead to cropland area expansion and forest extent to reduce (Dinda 2004; Mather et al 1999; Meyfroidt and Lambin 2011). After reaching a threshold, the forest extent increases and cropland extent decreases. While both the environment Kuznet curve and forest transition theories have held in high income countries and a number of medium income countries, the theories have followed different patterns in some developing and medium-income countries (Rudel et al. 2005; Defries et al. 2010). Forest transition in Ethiopia and Togo has not occurred due to lack of alternative employment and due to weak institutions to enhance tree planting and protection (Rudel et al. 2005). In other countries (namely Burundi, Rwanda, and Sierra Leone), civil wars led to deforestation (Ibid). However, strong policies and NGOs grassroot activities could lead to forest recovery and declining cropland. In Niger for example, the government passed a statue (*rural code*) giving land owners tenure security of any tree that they plant or protect (Larwanou et al. 2006; Adams et al. 2006). Planted forest area as a share of total forest area in Niger was 12 per cent in 2010 and was among the highest in SSA (FAO 2010). This achievement was a result of a combination of efforts by local communities, change in government policies and statutes, support from NGOs, and religious organizations and environmental stress, which prompted communities for a solution.

Foster and Rosenzweig (2003) also note that population pressure will have no significant impact on forest extent if government is effective enough to effectively enforce protected areas. Additionally, Esty and Porter (2005) noted that government effectiveness – government's capacity to implement policies with independence from political pressures and with respect to the rule of law (Kaufmann et al. 2010)—prevents or reduces environmental degradation.

However, the predictive power of the forest transition model and environment Kuznet curve has been reduced by globalization and the increased role of international trade (Rudel et al. 2009b). International trade enables a match of supply and demand of land-based products through virtual exchange of natural resources (Lambin and Meyfroidt 2011).

For example, recent analysis suggests that the relationship between rural populations and forest cover have weakened as globalization has linked well-capitalized ranchers, farmers and loggers, and their products with distant markets (Ibid). In what is referred to as displacement or Leakage effect—defined as displacement of land use from one place to another or migration of activities to another place due to land use policies in one country or region (Lambin and Meyfroidt 2011)—strict environmental policies could lead multinational companies to produce or buy agricultural products from developing countries with less restrictive environmental policies. For example in 2001, Switzerland imported agricultural products equivalent to 150 per cent of cultivated land area in the country (Wuertenberger et al. 2006).

We include the interaction terms which provide additional insights which cannot be captured by the individual variables. We examine the interaction terms which could have interaction effect on extent of cropland. Particularly we examine the interaction of population density with market access and poverty. Such examination will help us determine the impact of population density on cropland extent in areas with high market access or severe poverty. As discussed earlier, some empirical evidence (e.g. Grepperud 1996; Scherr 2000; Place and Otsuka 2002; Mäler 1997) has shown that in areas with severe poverty, population density could lead to land degradation, which in turn could lead to expansion of cropland.

6 Empirical model

We use a parametric multivariate regression approach to identify the effects of each the hypothesized drivers as discussed in the theoretical framework. Since our unit of analysis is the half-degree square pixel and the decision makers are the farmers in the pixel, we intended to estimate a Global OLS regression and local geographically weighted regressions (GWR). The motivation behind using GWR is that, it allows modelling of processes that vary over space (spatial non-stationarity), which gives more detailed spatial heterogeneity results at each pixel weighted by the neighbouring pixels. These local parameters from the GWR at each pixel could be mapped to display spatial differences in the estimated coefficients (Charlton et al. 2006). However, GWR was not feasible in our model due to convergence failure resulting from having no variation of country level covariates at pixel level (Scott and Janikas 2010). Additionally, GWR requires that no dummies are used as covariates (Ibid). Given that we have country-level dummy variables (land tenure) and that a number of variables are at country-level and therefore with no variation for all pixels within a country, GWR cannot be used in this model.

So we use, an alternative model which accommodates the nature of our analysis.

Following the discussion above, cropland area change is given by:

$$\Delta a = \beta_0 \Delta x_1 + \beta_1 \Delta x_1^2 + \beta_3 \Delta x_2 + \beta_4 \Delta x_3 + \beta_4 z + \beta_5 D + e_i$$

Where:

a = cropland area in pixel i, x_1 = vector of variables with quadratic relationship with Δa, which reflect the environment Kuznet curve. These include GDP, which represents economic development, international aid, and population density and agricultural expenditures on research and development, both of which reflect the Boserupian intensification theory; x_2 = a vector of variables with linear relationship with cropland area, namely agricultural export index; access to markets, and government effectiveness; D a vector of dummy variables representing land tenure; z = interaction terms of population density with access to markets and poverty; β_i = coefficients associated with the corresponding covariate i.

We correct for heteroskedasticity by estimating robust standard errors using White-Huber estimators. To ensure that the interaction terms are validly included in the model and that they are not highly correlated with the error term, we conducted the Wald tests and found that they were valid. However, due to the interaction terms and quadratic terms, the model has serious multicollinearity bias. Given that the interaction terms are valid and quadratic forms are consistent with theory, dropping them to avoid multicollinearity could lead to more biased and inconsistent estimates of parameters than the bias due multicollinearity (Berry and Feldman 1985). However, to check for robustness of our results, we include the linear model, whose variance inflation factor of all covariates was less than 10 and therefore did not have serious multicollinearity bias (Mukherjee et al. 1998). The discussion however will focus on the model with quadratic terms for reasons discussed above.

Household level characteristics—such as change in livelihoods, level of education, access to credit, etc.—also affect change in cropland extent. However, due to lack of household level panel data for the entire region, our empirical model does not include household level variables that could determine change in cropland extent. This is a weakness that needs to be taken into account when interpreting our results.

7 Data and descriptive statistics

We use the Ramankutty (2012) historical cropland data, which runs from 1700 to 2007[7] and is at 0.5 degree resolution.[8] The data were compiled from agriculture inventory and calibrated using satellite data. The 1987-2007 data were derived from satellite imagery while the 1700-1986 were from census statistics, land surveys and estimates by historians. This means, except for 1973-86, the data used (1973-2007) in this study were derived from satellite imagery. The data from SSA is poor and should be interpreted with care (Ramankutty 2012). Additionally, croplands are defined differently across countries and this adds to the inaccuracies of the census data. The satellite imagery data could also differ with ground observation due to difficult of observing differences between crops and non-crop plants. This is especially a problem for tree crops (Ibid).

Setting 1973-83 as baseline and 1997-2003 as endline, Figure 14 shows the change in cropland area as share of total land area in a half degree cell. Majority of countries experienced a moderate area increase ranging from 0.001 to 0.05 (yellow) of a half degree. This is a large area ranging from 309 ha to 15490 ha per half degree square area, which is about 309,800.5 ha (see footnote 8). Uganda, Nigeria, and a few other western African countries experienced significant increase in cropland area. Of great interest are countries which experienced a decrease in cropland extent.

While such decrease in all countries can be explained by growth of non-farm activities (Botswana, Gabon, and Western Namibia) a decrease of land area in Ethiopia appears to be due to data errors. In DRC and Somalia, the decrease in land area could have been due to civil war and insecurity. Botswana is of particular interest since it has invested the largest share of its agricultural GDP to R&D, is among countries with highest government effectiveness index and scores the lowest global hunger index in the region and has seen a decline in cropland extent. What has driven these favourable outcomes in Botswana?

7.1 Potential yield and actual yield

This represents the biophysical characteristics which determine the yield. We use yield potential of maize since the crop is the most important in the region (IITA 2013).[9] Maize is more important in east and central Africa where it accounts for 30-50 per cent of low-income household expenditures (Ibid). Dixon et al. (2001) also reported that maize farming system is the most common farming system in the region covering 15 per cent of the land area and is grown by 10 per cent of the agricultural population.

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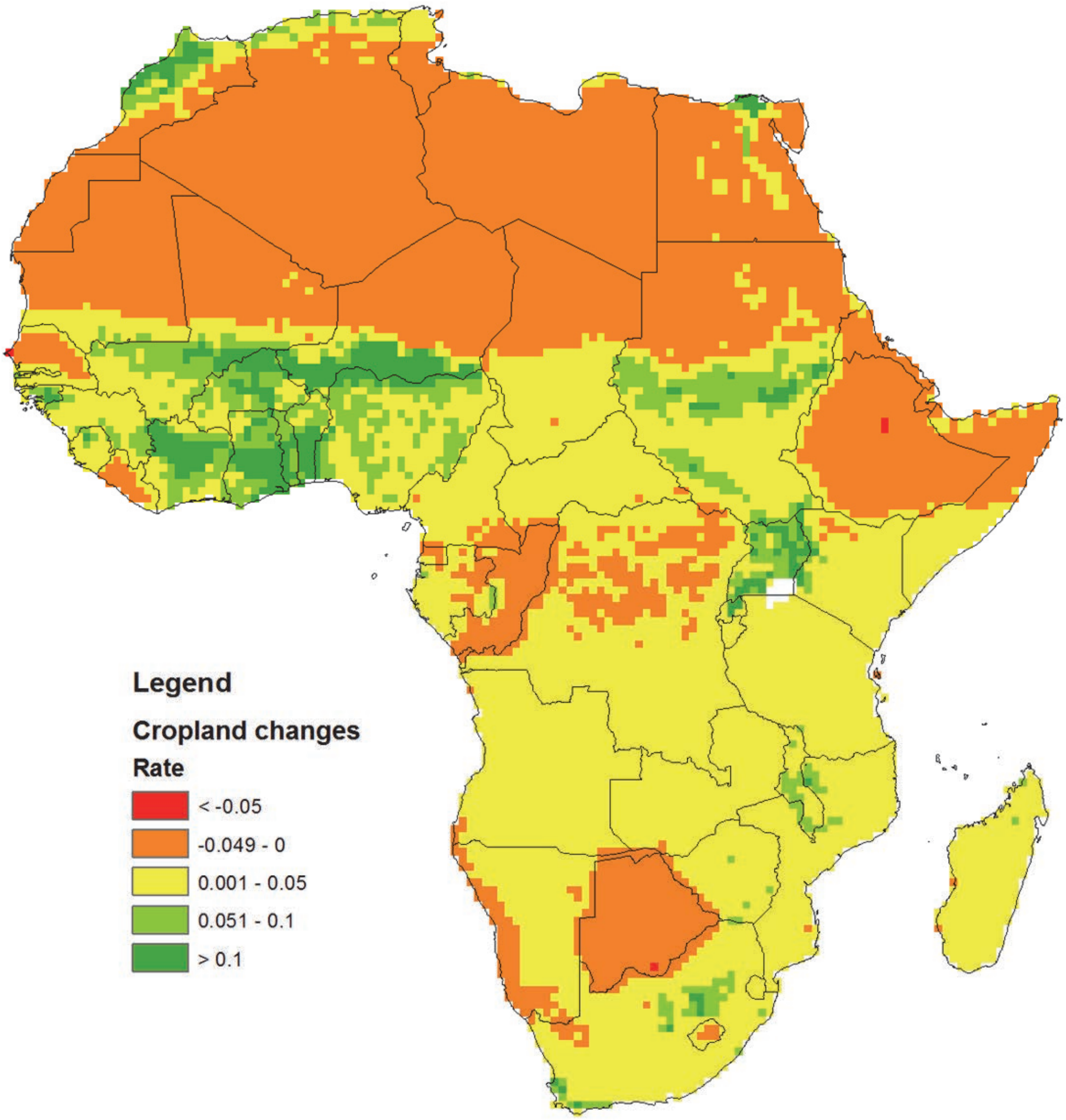
[7] Available online at: http://www.geog.mcgill.ca/~nramankutty/Datasets/Datasets.html

[8] The cropland area is a fraction of a half-degree grid cell. Assuming flat surface, a half grid square degree ≈ 309,800.5ha [distance along the equator is 40,075km, which is 360^o long. Hence, the area of a half degree square is given by: 0.5^o x 0.5^o = $\left[\frac{(40075\ x\ 0.5)}{360}\right]^2$ = 309,800.5ha.

[9] http://www.iita.org/maize

Figure 14: cropland area change, 1973-83 to 1997-2006



Source: Computed from Ramankutty (2012).

Country-level potential yield of maize was retrieved from the FAO Global Agro-Ecological Zones (GAEZ) v3.0 (IIASA/FAO 2012). The maize yield potential covers all arable land—including areas with no maize production. The GAEZ database provides vast amount of spatial data for assessing agricultural resources and potential covering five thematic areas[10] estimated through seven sequential modules.[11] The potential crop yields at different input levels (e.g. low, intermediate, and high level inputs) and water management scheme (e.g., rainfed, rainfed with water conservation, and three types of irrigation systems) are estimated

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10 GAEZ's five thematic areas: (1) land and water resources; (2) agro-climatic resources; (3) suitability and potential yields; (4) actual yields and production; and (5) yield and production gaps.

11 GAEZ's seven modules: (1) agro-climatic data analysis; (2) biomass and yield; (3) agro-climatic constraints; (4) agro-edaphic constraints; (5) crop potentials; (6) current crop production; and (7) yield and production gaps.

at the fifth step, after applying the inherent agro-climatic and agro-edaphic constraints to climatic potential yield, which is the theoretical potential yield under given climate condition with no abiotic or biotic constraints. To represent smallholder farmers production systems in this study, we used the maize yield potential under the rainfed low-level inputs, which assumes the traditional, subsistence management using traditional cultivars, labour intensive techniques, and no application of nutrients, no use of chemicals for pest and disease control and minimum conservation measures. For the climate scenario, we used the baseline period, which reflects average climatic conditions for the period of 1961-1990.

Box 2 discusses this question.

Box 2: Botswana, the success story of SSA

The entire land area of Botswana is classified as drylands (White and Nackoney 2003). Consequently, Botswana has one of the smallest carbon density and per capita freshwater in SSA (Table 2). The ODA assistance as per cent of GDP is also among the lowest in the region. Yet Botswana's grew at an average of about 5 per cent between 1994-2011 to become one of the fastest growing economies in the world (World Bank 2013). The country is among the few SSA countries in the upper middle income ((Ibid) with low hunger index and the country ranks well in other measures of human development indicators (UNDP 2013). Good governance and mineral resources are among the factors which have driven Botswana's consistent growth. Botswana is among the four countries with government effectiveness index above zero (Table 2 and Table 4). In an effort to diversify its economy from the mining sector and to address entrenched poverty in rural areas, Botswana invested the largest share of agricultural GDP to R&D (Table 2). As a result of this investment and the growing non-farm sectors, Botswana is among the few SSA countries which have experienced a declining cropland extent (Figure 14).

Comparison of Botswana and DRC underline the impact of good governance, investment in R&D and infrastructure and other key services and sectors on economic development. These factors and other factors mediate the country's potential to exploit efficiently its natural resource endowment.

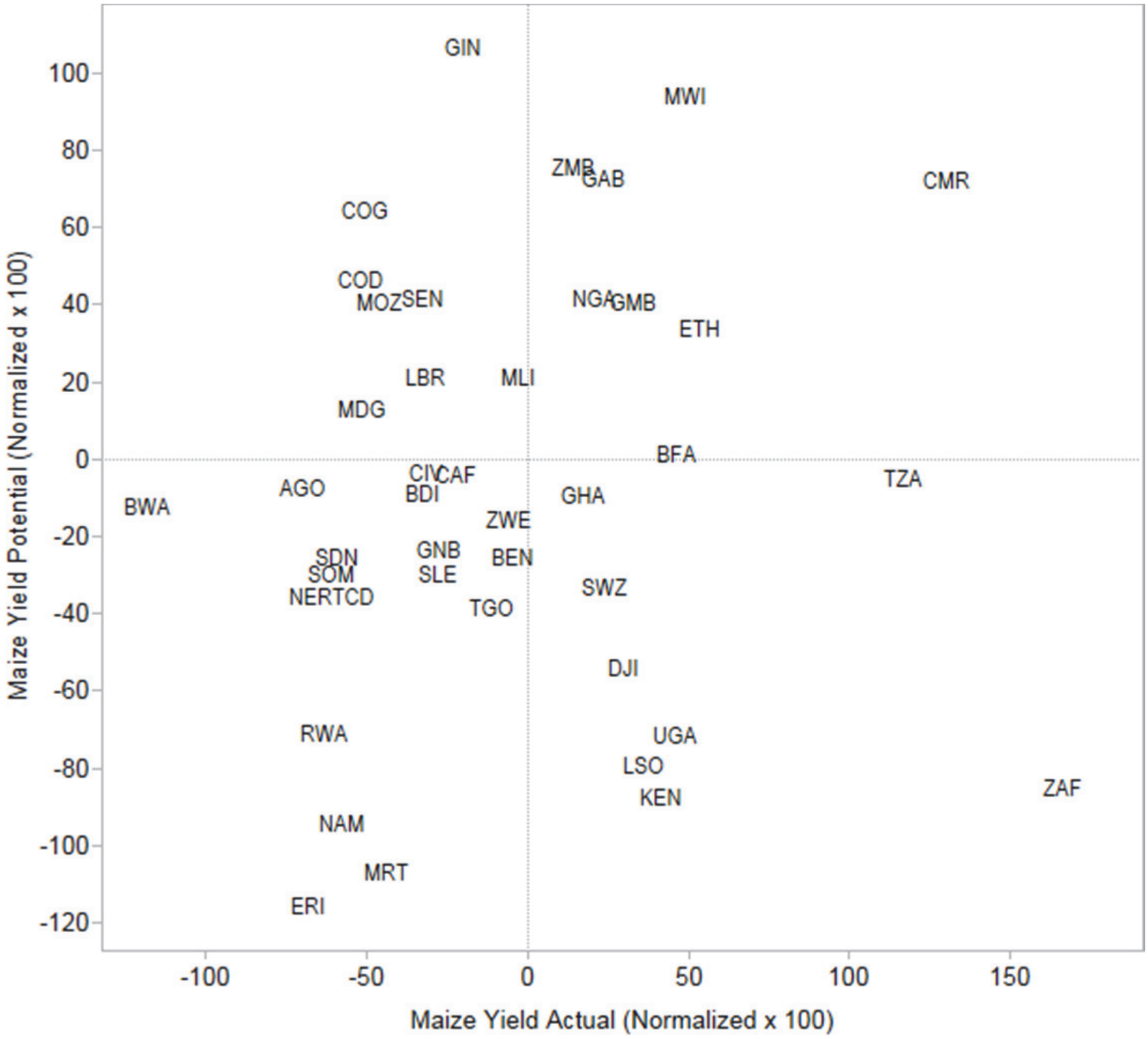
Table 2: Botswana and DRC compared

	Botswana	DRC	SSA
Carbon density (tons/ha)	3.83	65.59	18.03
Freshwater (m^3/capita) 2010	6.87	20.40	7.05
GDP per capita current US$ 2010	7426.63	198.71	1337.58
Road density index	2.82	1.27	2.29
Government effectiveness	0.42	-1.25	-0.68
R&D expenditure as & of Ag GDP	4.0	-	0.6
Aid as % of GDP (avg 1991-2010)	1.05	19.08	2.86

Sources: See sources for
Table 6.

Actual maize yield can help to determine the production technologies used by farmers under varying agricultural potential. Some countries with low agricultural potential may achieve greater yield if there is sufficient investment which enhance agricultural productivity. We divided the SSA countries into four quadrants based on all four combinations of agricultural potential and actual maize yield (Figure 15). Results show that countries in quadrant four (Q4)—South Africa, Kenya, Tanzania, Ghana, and Swaziland—with relatively low agricultural potential achieved relatively higher yield largely due to greater investment in

Figure 15: Agricultural potential and actual normalized maize yield in SSA



Notes: The country abbreviations are according to UN codes available at: http://unstats.un.org/unsd/methods/m49/m49alpha.htm

Source: Koo (2013).

agriculture (e.g. Beintema and Stads 2011) show that both Kenya, Ghana, Tanzania were among the eight countries which accounted for 70 per cent of SSA's R&D spending in 2008). On the other hand, countries in Q2—Mozambique, Guinea and Mali—achieved lower yield even though they have greater potential.[12]

Since, the major objective of this study is to examine the factors which contribute to cropland expansion and indirectly intensification and higher productivity, the observed actual and potential yield pattern will be examined further in the results section.

[12] For Mali, the northern arid zone is excluded as it is not arable.

7.2 Road connectivity and population density

We use travel time to the nearest urban area with 50,000 population or more. Past research has shown a strong correlation between agricultural production and proximity to urban areas (Dorosh et al. 2009). We used UNEP road data (Nelson 2007) and the Global Rural-Urban Mapping Project (GRUMP) population data from the Center for International Earth Science Information Network (CIESIN) to identify the urban areas with 50,000 or more population.[13] A one hour delay is added for travel across international borders.

SSA has the worst access to markets and consequently the highest transaction costs and water and energy tariffs in the world (Table 3). This has implications on change in cropland extent since access to markets could either lead to increase in cropland extent (e.g. see Fearnside (2002); Peres (2001)) or could lead to intensification and engagement in non-farm activities, which in turn could lead to decrease of cropland extent (e.g. see Haggblade et al. 2007). Simultaneously controlling for factors affecting change in cropland extent will help us isolate the impact of access to markets in this study.

Table 3: Africa's infrastructure deficit and cost

	Africa	Other developing countries
Paved road density (km/km^2 of arable land)[a]	0.34	1.34
Population with access to electricity (%)[a]	14	41
Population with access to improved potable water (%)[a]	61	72
Power tariffs ($/kwh)	0.02-0.46	0.05-0.1
Transportation cost ($/ton/km)	0.04-0.14	0.01-0.04
Tariffs of urban potable water ($/cu m)	0.86-6.56	0.03-0.6

[a] Excludes medium income African countries (South Africa, Kenya, Botswana, Gabon, Namibia, Cape Verde, etc.) and is compared to other low income countries. The rest of the statistics refers to entire Africa and other developing countries.

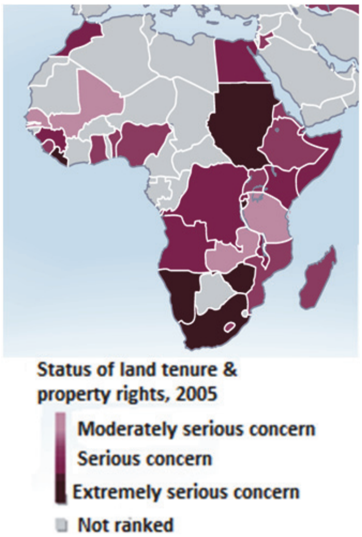
Source: Foster and Briceno-Garmendia (2010).

7.3 Land tenure

We use tenure security, which is threat or absence of likelihood of land expropriation by government or elites. USAID and ARD (2008) used country-level land policies and past history of land expropriation to give a country level tenure security (Figure 16). The land tenure security is divided into three major groups—(i) Moderately serious concern. This group includes countries where land users/owners have the least concern about expropriation. Examples of such countries include: Mali, Senegal, Tanzania, and Zambia (ii) Serious concern, which is medium threat of expropriation, examples of which include DRC, Ethiopia, Kenya, and Nigeria. (iii) Extremely serious concern of expropriation. This is the group with the worst land tenure security and includes such countries as Zimbabwe, and Sudan. Surprisingly even South Africa and Namibia are included in this group.

13 http://sedac.ciesin.columbia.edu/plue/gpw

Figure 16: Land tenure in SSA



Source: USAID and ARD inc. 2008; www.usaidlandtenure.net

7.4 Government effectiveness

We use the World Bank measure of government effectiveness index, which measures the quality of public services, civil service and the degree of its independence from political pressures. The index—which ranges from -2.5 (very poor performance) to 2.5 (excellent performance)—also measures the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies.

The average government effectiveness index (GEI) in SSA in 2005-07 was -0.76. Using the average GEI in 2005-07, we divided countries in three groups, poor government effectiveness, whose GEI was less than -1.0; medium performance (-1.0 < GEI < 0.0), and better performance (GEI ≥ 0) Table 4 shows that majority of the countries in the region have poor government effectiveness (GEI<0). The global average in 2005-07 was GEI = 0.[14] Compared to other regions in the world, SSA has the largest share of countries in the poor performance category and the smallest share of countries in the best performance group (Table 5).

Table 4: SSA government effectiveness index, 2005-07

Group	Per cent of SSA countries	Countries
Worst (GEI ≤-1)	31	Angola, Burundi, Central African Republic, Chad, Comoros, Congo, DRC, Equatorial Guinea, Eritrea, Guinea, Guinea-Bissau, Liberia, Sierra Leone, Somalia, Sudan, Zimbabwe
Medium: -1 <GEI <0	58	Benin, Burkina Faso, Cameroon, Cape Verde, Côte d'Ivoire, Djibouti, Gabon, Gambia, Ghana, Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritania, Mozambique, Niger, Nigeria, Sao Tome & Principe, Senegal, Seychelles, Swaziland, Tanzania, Togo, Uganda, Zambia
Best: GEI≥0	9	Botswana, Mauritius, Namibia, and South Africa

Source: Compiled from Kaufmann et al. (2010).

14 The exact GEI=-0.00306.

Table 5: Government effectiveness index of all regions, across groups

	Very poor (GEI ≤-1)		Medium (-1 <GEI <0)		Best (GEI≥0)	
	GEI[1]	%[2]	GEI[1]	%[2]	GEI[1]	%[2]
SSA	-1.4	31	-0.5	58	0.6	9
LAC	-1.5	3	-0.5	27	0.8	70
North America		0		0	1.3	100
South Asia	-1.2	10	-0.6	50	0.5	40
Asia and the Pacific	-1.5	15	-0.5	45	0.9	40
Europe	-1.5	2	-0.3	21	1.2	76
Near East	-1.4	30	-0.5	30	0.6	40
Global	-1.4	16	-0.5	38	0.9	46

Notes: [1] Average GEI in corresponding group
[2] Per cent of countries in the region belonging to corresponding group

Source: Compiled from Kaufmann et al. (2010).

7.5 Infant mortality rate (IMR) of 1,000 of live births

The IMR is a good indicator of poverty and has been used in many poverty studies. (e.g. see Dasgupta 2010). We use the IMR to represent the impact of poverty on cropland extent. IMR data are at half degree resolution and are obtained from CISIEN.[15]

Table 6 summarizes the data used, their sources and baseline and endline periods. As far as possible, the baseline and endline periods of all the covariates were matched with the corresponding periods for cropland area. For some variables, data for the baseline period (1973-83) were not available. Hence, an alternative period which is as close as possible to the 1973-83 periods was used. These include GEI, population density at half degree resolution.

8 Econometric results

As expected expenditures on agricultural research and development (hereafter referred simply as R&D expenditure) has a quadratic relationship with change in cropland extent (Table 7). This is consistent with Rudel et al. (2009) who showed that crop yield and cropland area first increase simultaneously and then cropland extent falls after reaching a threshold. The level at which R&D expenditure leads to a decrease in cropland area is when a US$1 million R&D expenditure leads to a cropland expansion of 878 ha in a half-degree grid cell of about 309,800 ha (see footnote 8).

Change in GDP portrays a U-shaped pattern. Increase in GDP first decreases cropland area as expected but increases it after reaching a threshold. However, the expected pattern was an inverted U. The results suggest that the predominantly agricultural economies could lead to cropland expansion as the economy grows. Further investigation is required to understand the pattern of African economies which remain dominated by smallholder farmers. The results also underline the continued predominance of agriculture as engine of economic growth in

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15 http://sedac.ciesin.columbia.edu/povmap/methods_global.jsp

SSA. This is consistent with data which show only few countries which have experienced a declining cropland area.

Table 6: Summary of data sources, resolution and baseline and endline periods

Data type	Resolution	Baseline and endline periods	Source
Biophysical data			
Yield potential	Country-level	Fixed	FAO - Global Agro-Ecological Zones (GAEZ) v3.0 (IIASA/FAO 2012)
Cropland expansion –	0.5^o x 0.5^o	Baseline: 1973-83 Endline: 1997-2007	Ramankutty data
Socio-economic data			
Total bilateral aid disbursement to all sectors	Country-level	Baseline: 1973-83 Endline: 1997-2007	http://www.oecd.org/dac/stats/
Road density	0.5^o x 0.5^o	Fixed:	Nelson 2007
IMR (infant mortality rate)	0.5^o x 0.5^o	Single period: 2005	CISIEN (2010) http://sedac.ciesin.columbia.edu/povmap/
Government effectiveness[a]	Country-level	Baseline:1996–98 Endline: 2005–07	http://info.worldbank.org/governance/wgi/index.asp
Population density	0.5^o x 0.5^o	Baseline: 1990 Endline: 2007	http://sedac.ciesin.columbia.edu/plue/gpw
GDP	Country-level	Baseline: 1973-83 Endline: 1997-2007	IMF: www.imf.org/external/pubs/ft/weo/2010/02/
Agricultural R&D expenditure	Country-level	Baseline: 1973-83 Endline: 1997-2007	ASTI: http://www.asti.cgiar.org
Agricultural export quantity index	Country-level	Baseline: 1973-83[b] Endline: 1997-2007	FAOSTAT

Notes: [a] Government effectiveness index (GEI) is based on 17 component sources, measures the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies. The index values range from -2.5 (very poor performance) to +2.5 (excellent performance) Kaufmann et al. (2010).

Source: see last column of Table.

Table 7: Drivers of extent of cropland – robust OLS regression

Explanatory variables	Quadratic	Linear
Agric R&D expenditure (US$ million)	82.526***	18.313***
Square R&D expenditure (US$ million)	-0.094***	
GDP (US$ billion)	-132.387***	-47.259***
Square GDP (US$ billion)	0.255***	
ODA (US$ million, constant price 1982-84)	470.412***	124.712***
ODA^2	-2.156*	
Agricultural exports quantity index	-4.293**	-0.731*
Travel time (minutes) to urban area with 50k people	-2.944***	-3.259***
Rural population	182.065***	75.656***
Square rural population	-0.353***	
Yield potential (000 tons/ha)	-36260.939***	-28555.001***
Infant mortality rate (IMR) per 1,000 live births	-1.441**	-1.226*
Government effectiveness (index)	4454.449***	3410.208***
Land tenure (cf extremely serious concern)		
- Less severe concern	-7848.546***	-1768.952***
- Serious concern	-6464.628***	-1717.513***
Rural population X poverty (IMR)	0.013***	0.013**
Rural population X market access	-0.158***	-0.123***
Constant	17157.024***	15753.314***
R^2	0.28	0.23
Wald test for joint significance of covariates (P-Value)	0.000***	0.000***
Breusch-Pagan test for Heteroskedasticity (P-Value)	0.000***	0.000***
White's test for Heteroskedasticity (P-Value)	0.000***	0.000***

Note: Standard errors are corrected for heteroskedasticity using Huber-White estimators. *, **, and *** respectively mean the corresponding coefficient is significant at P = 0.10, 0.05 and 0.01.

Source: Authors.

As expected, ODA support has an inverted U relationship with cropland area expansion. The results suggest that the ODA support will lead to agricultural intensification after a threshold is attained when key outcomes it supports enhances agricultural intensification. As shown in Figure 12, countries in which ODA as share of GDP is largest also has the largest cropland expansion suggesting the current level of support still spurs more cropland expansion than intensification. Contrary to Lambin and Meyfroidt (2011) agricultural export volume index decreases cropland area expansion underscoring the impact of international trade on agricultural intensification. It is well-established that management practices of export crops are much greater than the domestically consumed crops (Kelly 2006; Crawford et al. 2003). For example, fertilizer application and use of improved varieties is greater for high-value and export crops than on other crops (Ibid). However, the recent large foreign agricultural investment in SSA with heavy orientation to meeting food and energy needs of investing countries rather than for domestic consumption (Anseeuw et al. 2012; World Bank 2011) could trigger cropland expansion into forested areas even when there is intensification.

Proximity to urban areas and roads leads to greater cropland extent. The results are consistent for both the linear and quadratic models and imply that improvement of market infrastructure could lead to cropland expansion even after controlling for population density and other key covariates. The result imply that even if farmers closer to markets are likely to intensify crop production, they could still expand cropland area to exploit the high returns due to lower transaction costs and high farm gate prices. Additionally, the market access x rural population density interaction term suggests that improvement of market access could lead to cropland expansion in areas with high market access and population density. This is consistent with Rudel et al. (2009a) results for South Asia where population density and market access have improved (Pingali 2007) while crop yield and cropland area have also simultaneously increased (Figure 13).This demonstrates the high demand for agricultural products that could potentially lead cropland expansion even in cases where there is intensification. This calls for stricter rules and regulations to prevent deforestation when countries and donors support improvement of market access infrastructure in SSA. Yield potential leads to reduced cropland area, suggesting that cropland expansion in high potential areas is likely to be slower than areas with low agricultural potential. Controlling for other factors, poverty—as measured using infant mortality rate (IMR)—reduces cropland expansion. This is contrary to expectation and could be due to multicollinearity. However, population density and poverty interaction term shows the expected results, i.e. poverty enhances area expansion in areas with high population density. This is consistent with expectation of the vicious cycle of poverty and land degradation in poor rural areas (Grepperud 1996; Scherr 2000; Place and Otsuka 2002; Mäler 1997) since cropland expansion is likely to displace forests (Figure 7).

Contrary to Esty and Porter (2005), government effectiveness increases cropland extent in both the quadratic and linear models. This could be due to the security in countries with effective governance which allows farmers to increase cropland area. The result also suggests that at the current level of government effectiveness in most SSA countries, the effectiveness of environmental protection rules and regulations and their enforcement is limited and has not reached a level which could reduce cropland area expansion into forest and other non-crop areas. In countries which have experienced decrease in cropland, government effectiveness was high (e.g. Botswana GEI = 0.7). This suggests governance could have also contributed to decrease in cropland extent by limiting expansion into protected areas. For example, Mbaiwa et al. (2011) observed an effective protection of the Okavango delta using community-based natural resource management approach.

Land tenure security results imply that in countries with more secure land rights, the cropland expansion is slower. Recent foreign land acquisition in SSA is consistent with these results since such acquisitions have been concentrated in countries with weak tenure security (RRI 2013; HLPE 2011). The results further underline the importance of land rights to farmers in SSA.

9 Conclusions and policy implications

Results of this paper have important implications on the agricultural policies in SSA as the region increases efforts to reduce poverty and ensure food security. Public expenditure and on R&D and ODA support will lead to intensification and eventually reduce the cropland extent, which increases largely at the expense of forest cover. Cropland expansion remains highest in countries with highest ODA assistance as share of GDP. Additionally, current agricultural R&D investment in most SSA countries remain low as only eight countries (Mauritania, Uganda, Kenya, Burundi, South Africa, Namibia, Mauritius, and Botswana) have surpassed the New Partnership for Africa's Development (NEPAD) target of spending one per cent of agricultural GDP on R&D (Beintema and Stads 2011). Botswana—which spends the largest share of agricultural GDP on R&D (about four per cent) (Ibid)—has already experienced a decline in cropland extent. Investment in R&D will contribute to sustainably exploiting SSA's large unused arable land and wide yield gap, both of which provide a large potential for producing food for its growing population and the rest of the world.

Controlling for government effectiveness, population density and expenditure on R&D and other factors, our results further show that improvement of access to markets could lead to expansion of cropland extent. Given the large infrastructure deficit in SSA, our result imply that investment in improvement of access to markets should be accompanied with more effective environmental protection to prevent deforestation and other land conversions which could lead to land degradation—an outcome, which will negatively affect the poor who heavily depend on natural resources.

Increasing agricultural export will increase agricultural intensification and reduce cropland area expansion. However, recent foreign land acquisition in SSA could lead to simultaneous cropland intensification and expansion. This suggests the importance of simultaneously increasing R&D, access to markets and capacity of governments to enforce environmentally friendly rules and regulations. This could lead to increasing agricultural productivity and preventing deforestation and other forms of land degradation.

Overall, our results imply that SSA can effectively exploit its large agricultural potential by simultaneously increasing investment in R&D and market infrastructure—both of which remain under-invested in the region. International assistance should also be designed such that it balances more effectively economic growth with environmental protection. This could be done by increasing support for environmental governance. The ODA support to agriculture and other land-based sectors—which has declined from its level in the 1980s need to be increased with special emphasis on environmental protection to prevent the ongoing cropland expansion into forested areas.

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Appendix 1: Forest and cropland area change and their relationship with ODA support in SSA

Country	Aid as % of GDP, 1986-95	Forest trend 2001-10	Cropland change, 2001-10
High deforestation rate			
Comoros	12.6	-50.0	11.2
Togo	8.0	-35.7	4.5
Nigeria	0.5	-28.3	15.7
Mauritania	11.3	-26.4	-10.7
Burundi	10.5	-25.4	2.7
Niger	11.5	-23.0	8.9
Uganda	5.9	-21.5	17.3
Ghana	4.9	-19.4	39.9
Zimbabwe	4.2	-16.7	21.8
Benin	7.4	-11.6	36.3
Tanzania	15.4	-10.7	16.1
Cameroon	3.1	-10.0	0.9
Burkina Faso	9.7	-9.6	41.8
Ethiopia	4.9	-9.5	23.3
Botswana	3.3	-9.5	-26.7
Malawi	12.3	-9.3	29.8
Namibia	2.5	-9.2	7.3
Medium-low deforestation			
Mauritius	1.8	-7.9	-9.7
Sierra Leone	8.2	-6.8	96.4
Equatorial Guinea	21.8	-6.8	-7.0
Liberia	12.7	-6.6	15.0
Chad	9.2	-6.5	20.4
Mali	11.8	-6.1	58.2
Mozambique	42.8	-5.4	25.0
Guinea	6.1	-5.3	4.2
Senegal	8.5	-5.1	9.1
Guinea-Bissau	30.8	-4.7	25.4
Madagascar	7.4	-4.5	7.2
Kenya	6.6	-3.5	4.6
Zambia	14.8	-3.4	6.8
Angola	2.5	-2.2	7.3
DRC	3.5	-2.1	-3.3
CAR	8.5	-1.4	-0.9
Congo, Rep.	5.8	-0.8	3.3
Increase in forest area			
Gabon	2.4	0.0	3.4
Seychelles	5.1	0.0	-10.0
South Africa	0.1	0.0	-2.3
Côte d'Ivoire	4.5	1.1	7.2
Gambia, The	14.3	4.5	69.4
Lesotho	13.0	5.1	-1.2
Swaziland	3.0	9.7	0.3
Rwanda	15.4	18.4	27.1
Cape Verde	23.7	19.7	10.0

Note: Forest and cropland trend $=\left(\frac{a_2-a_1}{a_1}\right)x100$, where a_1 = average area in 1986-95 and a_2 = average area, 2001-10.

Sources: FAOSTAT (deforestation and cropland area), ODA (aid) and World Bank (GDP).