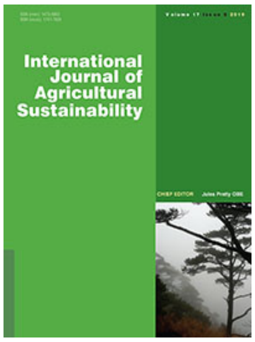

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Drivers, farmers' responses and landscape consequences of smallholder farming systems changes in southern Ethiopia

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ABSTRACT

Ethiopia is now the second most populated country in Africa with more than 100 million people and an annual population growth rate of 3%. Here, we assess how the on-going expansion of arable land and urban areas is affecting the availability of common resources, such as forest and grazing land, and the availability of biomass for food, feed, and energy. Taking the Hawassa area in the Rift Valley of Ethiopia as a study case, this study aims at analysing the drivers of change of farming systems, assessing farmers' responses to these drivers and appreciating the consequences for the agricultural landscapes' composition. We found that (i) national-level policies, climate and soil fertility changes, population increase, and urban expansion were major drivers of farming systems change in the Hawassa area, (ii) forests and grasslands have been progressively replaced by cropland and urban areas, and (iii) these changes resulted in fragmentation and diversification of local agricultural landscapes with potential consequences for ecosystem service provision. Farmers responded with the following three main livelihood strategies: consolidation, diversification and specialization. These changes led to more diverse and fragmented agricultural landscapes. This research contributes to the ongoing debate about the viability of small farms.

1. Introduction

Farming systems are dynamic, complex socio-ecological systems that provide food, feed, and cash and result from past farmers' livelihood strategies and land use decisions. Farming system trajectories are the succession of chronological steps leading to structural or organizational changes in a population of individual farms sharing similar opportunities and constraints (Rueff & Gibon, 2010). Consequently, farming system changes and their drivers are heterogeneous and complex, varying between households, locations, and time (Carswell, 2000; Tittonell, Vanlauwe, Misiko, & Giller, 2011). Two main drivers, availability of farmland and access to market, are considered to have major effects on farmers' decision making in terms of production orientation, land allocation, livestock densities, and involvement in off/non-farm activities (Mellor, 2014; Muyanga & Jayne, 2014). However, the dynamics of these drivers, their link to regional and national level socio-economic context, and the response of farmers over time are poorly understood.

Farm sizes across sub-Saharan Africa have gradually declined over the past 50 years (Muyanga, Jayne, & Burke, 2013). The reduction in cropland is leading to expansion into forested areas and cultivation of steep slopes. Continuous cropping without adequate crop nutrition is also causing soil nutrient mining,

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erosion, and increasing risk of pests and disease outbreaks due to lack of crop rotations (Tittonell et al., 2010; Van Huis & Meerman, 1997; Zhang et al., 2018). The projected population increase is likely to lead to further structural and organizational changes in farming systems and can redirect trajectories with uncertain future outcomes in terms of food provision and income generation. While many studies analysed typologies of static farming systems at a certain point in time (Pacini et al., 2013; Tittonell, 2014), researchers often fail to understand how farming systems evolve in different directions by responding to historical and current drivers of change and how these changes shape the composition of landscapes in which farms are embedded (Carmona, Nahuelhual, Echeverría, & Báez, 2010). The lack of comparable information across intervals of time makes it difficult to assess whether rural livelihoods are diversifying or becoming more self-sufficient. Therefore, building more sustainable agricultural systems requires an understanding of the historical socio-ecological dynamics of farming systems, the drivers of change, and the direction of these changes (Valbuena, Groot, Mukalama, Gérard, & Tittonell, 2015).

Analysing trajectories of change of farming systems is particularly important for sub-Saharan Africa, which is experiencing fast changes in land cover/land use because of urbanization and population growth. Ethiopia is a good case to study the impact of these changes, as it is now the second most populated country in Africa with more than 100 million people and a population growth rate of 3% per year (World Bank, 2019). The ongoing expansion of arable land and urban areas is leading to increasing pressure on common resources, such as forests and grazing lands, and increasing biomass competition for food, feed, and energy (Assefa & Bork, 2014; Kindu, Schneider, Teketay, & Knoke, 2013). These changes have a direct effect on the composition and structure of agricultural landscapes and may affect current and future biodiversity and the ecological processes it supports. We analyse the ways in which socio-economic, political, and biophysical drivers from national to local scales influenced farmers' livelihood strategies. More specifically, the aims of this study were (i) to describe the drivers of farming systems changes in the Hawassa area, (ii) to analyse how farmers responded to these changes and the resulting trajectories of farming systems, and (iii) to explain how these changes shaped current agricultural landscapes and the possible ecological consequences this may have for agricultural production and ecosystem services.

2. Materials and methods

Data were collected in five steps (Table 1). A farm household survey with 173 respondents was conducted in 2013, followed by focus group discussions which consisted of three activities: the assessment of perceived drivers of change, land cover/land use changes, and participatory typology of current farming systems. Based on the participatory typology, a subsample of 15 farms for each of the 4 types as resulting from the participatory typology were selected among the 173 respondents for a statistical typology of farming system trajectories. A quantitative satellite image analysis complemented the farmers' perceived land cover/land use changes. Population and climate information were gathered from national statistical data and other secondary data.

2.1. Study area

The study was conducted in the Hawassa area in the Sidama zone, which belongs to the 'Southern

Table 1. Data collection approach.

Step	Data source	Period covered or year	Analysis or outcome
1	**Household survey** (173 respondents)	2013	Descriptive statistics of current farming systems
2	**Focus group discussions** (20 participants per district)	1965–2015	Drivers of change and land cover and land use changes as per farmers' perception Participatory typology of current farm types
3	**Household survey** (15 respondents per current fam type ($n = 60$))	Between the year of farm settlement and 2015	Statistical typology of trajectories of change of farming systems
4	**Landsat satellite images classification**	1984–1998 and 1998–2014	Quantitative land cover/land use change analysis (area change)
5	**Secondary data**	1980–2018	Drivers of change (socio-economic national statistical data) Weather (rainfall and temperature) Literature

Nations, Nationalities, and Peoples' (SNNPR) province in the Ethiopian Rift Valley (7°03′11″ to 7°08′4″ N latitude and 38°15′17″ to 38°38′47″E longitude; Figure 1). The study area is located within one of the most densely populated areas of Ethiopia. Hawassa town has been experiencing continuous population growth from 10,000 in 1978 to more than 300,000 in 2015 (Dessie, 2007). This growth is partly due to rural-urban migration, which was 7.28% in SNNPR between 1994 and 2007, and higher than the national average of 5.68% (Eshetu & Beshir, 2017). The area is characterized by moist to sub-humid, warm subtropical climate with an average temperature of 15–20°C. Annual precipitation ranges from 1000 to 1800 mm in a bimodal distribution pattern, expected in March to April and June to August (Dessie, 2007). Historical rainfall patterns show a high variability, with lowest annual precipitation reaching 700 mm in some years. Three districts were selected: Wondo Genet, Tula, and Hawassa Zuria with an altitude of 1712, 1730 and 1700 m, respectively. Each district is characterized by contrasting farming systems, as illustrated by differences in area of perennial and annual crops, field sizes and livelihoods (Table 2). The three districts are dominated by mixed crop-livestock farming systems with a variable level of integration between the crop and the livestock sub-components.

2.2. Household survey

In 2013, a semi-structured farm household survey was conducted in the three districts to assess current farming system changes. Households were randomly selected along three transects from the lake Hawassa to the inland in each district (i.e. 9 transects in total). A total of 173 households were selected (55 in Hawassa Zuria, 64 in Tula and 54 in Wondo Genet). The survey captured general information about the respondent (head of the household), household composition, and main constraints in the farming

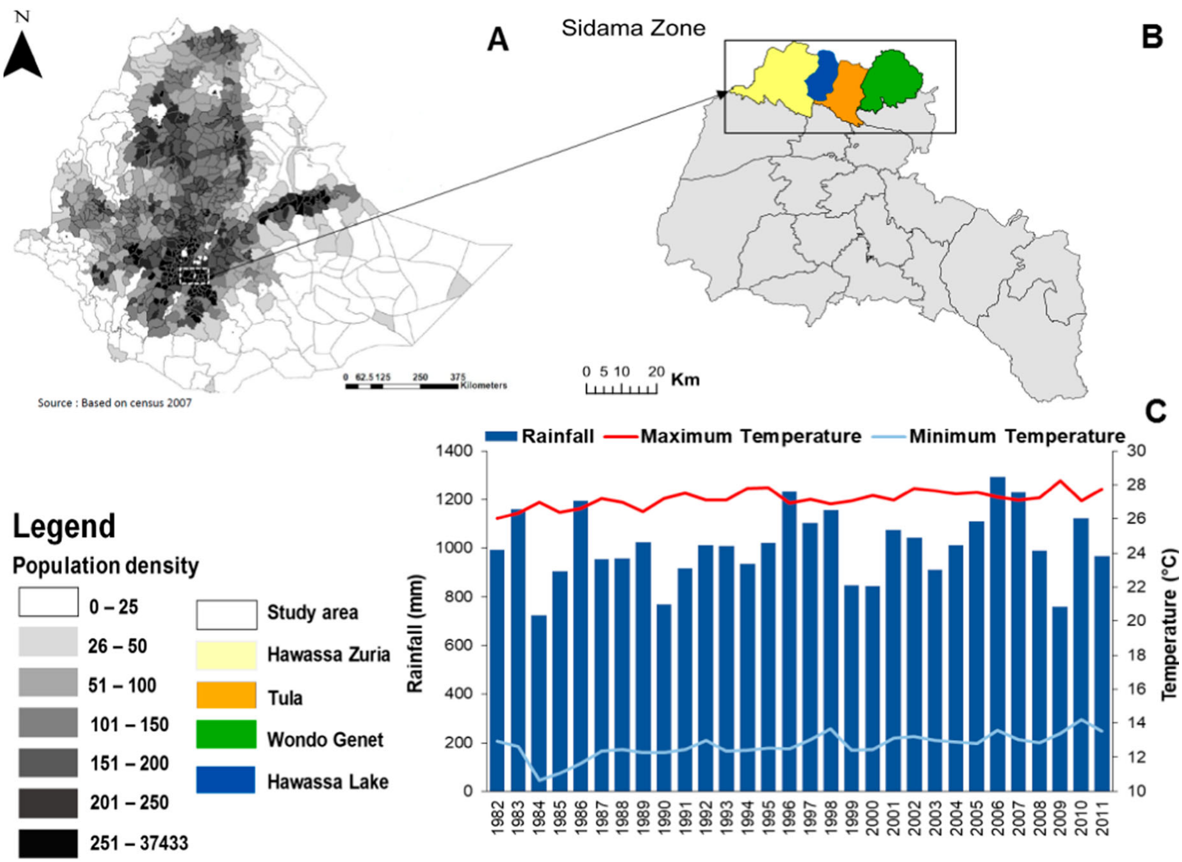

Figure 1. Population density in Ethiopia based on 2007 census (A), location of the study area and the selected three districts: Hawassa Zuria, Tula, Wondo Genet (B), annual mean rainfall, minimum and maximum temperature in the Hawassa area (C).

Table 2. Selected variables describing current farming systems by district (mean ± standard deviation).

	Hawassa Zuria	Tula	Wondo Genet
Respondent age	39.45 ± 12.99	47.01 ± 13.82	44.03 ± 13.54
Household size	6.75 ± 2.42	8.01 ± 3.73	7.49 ± 3.00
Respondent education level (number of years of attendance)	2.67 ± 3.20	3.09 ± 3.70	4.48 ± 3.72
Spouse education level	1.54 ± 2.79	1.43 ± 2.78	1.80 ± 2.58
Area of coffee (ha)	0	0.06 ± 0.09	0.05 ± 0.08
Area of enset (ha)	0.13 ± 1.14	0.23 ± 1.15	0.12 ± 0.10
Area of khat (ha)	0.03 ± 0.11	0.14 ± 0.15	0.27 ± 0.25
Area of maize (ha)	0.74 ± 0.50	0.44 ± 0.35	0.26 ± 0.23
Area of common bean (ha)	0.03 ± 0.08	0.004 ± 0.031	0.004 ± 0.034
Area of other crops	0.06 ± 0.09	0.01 ± 0.05	0.04 ± 0.14
Total area (ha)	1 ± 0.62	0.91 ± 0.57	0.78 ± 0.51
Livestock (TLU/household)	2.91 ± 2.34	2.09 ± 1.85	2.04 ± 1.88
Milk production (Litter/cow/day)	0.95 ± 1.31	1.06 ± 1.82	0.94 ± 1.32
Milk consumption (Litter/cow/day)	0.91 ± 1.21	1.01 ± 1.81	0.86 ± 1.26
Manure (kg/ha)	526 ± 1061	597 ± 1110	605 ± 1025
DAP (kg/ha)	74.45 ± 60.16	48.67 ± 125.73	42.62 ± 51.39
Urea (kg/ha)	77.45 ± 60.92	34.08 ± 26.83	47.16 ± 51.41
Use of pesticide (Litter/ha)	0.49 ± 3.36	0.25 ± 0.72	0.08 ± 0.37
Households having amobile phone (%)	65	45	68
Households having a radio (%)	25.45	25	38.88
Primary source of cash	Maize (76%)	Khat (41%)	Khat (87%)
Second source of cash	Common bean (33%)	Coffee (33%)	Coffee (46%)
Third source of cash	Cattle (16%)	Cattle (14%)	Cattle (26%)

system, area allocated to different crops and total farm size, input use, livestock number, and feed sources. Livestock numbers were further converted into tropical livestock units (TLU) (Jahnke & Jahnke, 1982). This survey provided insight on current farming systems and cash sources (Table 2).

2.3. Focus group discussion

Focus group discussions were conducted with 20 key informants in each district. The discussions led to three outputs: (i) a timeline construction to capture the perception of historical drivers of change and identify key periods and drivers that have influenced farming systems from 1974 until 2015, (ii) a participatory mapping and bar graphing to assess the changes in land cover and land use changes, and (iii) a participatory farm typology of current farm types.

2.4. Survey for trajectories of change of farming systems

Based on the participatory typology, a subsample of five farms per type and per district was selected among the 173 respondents surveyed in 2013. A total of 60 farmers (three districts x four types x five farms) were interviewed to understand the trajectories of their farming systems. A detailed survey was conducted to assess changes in farm size, crop allocation, production orientation, livestock number, feed sources, off-farm activities, and food purchases during two points in time: the year when the household began farming and 2015. The average starting year was 1984 with a standard deviation ranging from 1969 to 1999.

2.5. Statistical typology of trajectories of change in farming systems

In order to assess the typology of trajectories of change in farming systems resulting from farmer's livelihood strategies, we assessed past and current farm structure and farm assets in two points in time. A statistical typology of trajectories of change was constructed based on the sub-sample of 60 farms considering the difference between the variables in the current situation (t_1) and the year of settlement (t_0). To test for correlations between the variables at t_0 and t_1, we assessed the Pearson correlation coefficients between the variables resulting from the detailed survey and have reduced the final set of variables to eight (Table 3). To quantify the change in variables, we used data from the year of settlement (t_0) and 2015 (t_1). The rate of change was then calculated as:

$$\Delta V = (Vt_1 - Vt_0)/(t_1 - t_0)$$

where ΔV is the annual change of the variable Vi between the time t_0 and the time t_1; Vt_0 is the value

Table 3. Selected variables for developing the statistical typology of farming system trajectories (mean ± standard deviation).

Variable	Unit	Year of settlement (t_0)	Current situation, 2015 ($t1$)
Land resources			
Household-level land available per capita (PerCapitaland)	ha	0.38 ± 0.24	0.09 ± 0.06
Cropping orientation			
Area dedicated to food crops (FoodCropArea)	ha	0.62 ± 0.38	0.45 ± 0.32
Area dedicated to cash crops (CashCropArea)	ha	0.07 ± 0.09	0.17 ± 0.15
Livestock management			
Livestock size per household	TLU[a]	6.07 ± 5.24	2.98 ± 4.23
Proportion of feed purchased (FeedPurchased)	%	2.93 ± 9.36	19.48 ± 17.51
Off-farm activities			
Proportion of off-farm income (InOffFarm)	%	5.86 ± 13.51	9.13 ± 14.54
Food purchase dependence			
Proportion of income used for food purchases (RatioExpFood)	%	11.81 ± 4.16	24.32 ± 6.18

[a]One Tropical Livestock Unit corresponds to a value of 250 kg live weight for 1 TLU (Le Houérou & Hoste, 1977). Sheep and goats were assumed to be equivalent to 0.1 TLU, donkeys 0.5 TLU, horses to 0.8 TLU and all types of cattle to 0.7 TLU (Jahnke & Jahnke, 1982).

of the variable *Vi* during the year of settlement; Vt_1 is the value of the variable *Vi* in 2015, and ($t_1 - t_0$) is the difference in years between the time t_1 and the time t_0.

Principal component analysis (PCA) was used to examine the rate of change of the selected variables, and the PCA output was used to partition the dataset into clusters (Bidogeza, Berentsen, De Graaff, & Oude Lansink, 2009; Cortez-Arriola et al., 2015; Tittonell et al., 2010). The number of principal components (PCs) was selected based on the Kaiser's criterion, i.e. all PCs with an eigenvalue exceeding 1 were retained (Hervé, 2011). The PCA output was further analysed using cluster analysis based on a hierarchical agglomerative clustering algorithm using the Ward's method. This algorithm progressively groups together the observations according to their similarity (measured by a dissimilarity index, Ward's minimum variance criterion), minimizing the augmentation of the total intra-class inertia (Ward, 1963). The resulting clusters were examined in terms of their position in two PCs planes defined by PCA1, PCA2, and PCA3 representing 28.1%, 18.3%, and 15.4% of the variability respectively. Three axes were necessary to explain 61.7% of the variability (Eigen-value = 1.07). The resulting clusters represent broad trajectories of farming systems between t_0 and t_1. All analyses were conducted using R software (version 3.6.0; R Core Team, 1999) with the chart correlation function from the Performance Analytics package for constructing correlation plots (Peterson et al., 2018) and the *ade4* package for PCA (Dray & Dufour, 2007).

2.6. Land cover change analysis using satellite images

A quantitative land cover analysis of the Hawassa area was conducted for 1984, 1998, and 2014, using Landsat 8 OLI/TIRS data for 2014 and Landsat 5 TM data for 1984 and 1998. The choice of years of image acquisition allowed for a comparison of the current state with the periods preceding and following the Communism period (the Derg), identified by farmers as an important political driver of change. All images had a 30 × 30 m resolution. Following the procedure described in Kebede et al. (2018), an object-based classification was conducted for 1984, 1998 and 2014 in which related pixels were grouped in objects using eCognition (Blaschke, 2010) and cropped and non-cropped areas could be distinguished. Using a phenology-based classification approach, cropland was further subdivided into the following classes: annual, perennial, perennial dominated mixed crops, and annual dominated mixed crops (Wang, Franklin, Guo, & Cattet, 2010). Fields were classified as mixed crops when their size was smaller than the resolution of the image (30×30 m) and could not be classified as annual or perennial crops. Changes in land cover were assessed as the difference in the land cover class (in ha and percentage) through pixel-by-pixel comparisons between 1984 and 1998 and between 1998 and 2014 using Erdas software (Lu, Mausel, Brondízio, & Moran, 2004).

3. Results

3.1. Description of current farming systems

The farm survey indicated that respondents were mostly male (88%) with a mean age between 40 and 50 years, while the average household size ranged between seven and eight members increasing from Hawassa Zuria to Wondo Genet (Table 2). The main food crops were maize (*Zea mays*) and enset (*Ensete ventricosum*), while the main cash crops were khat

(*Catha edulis*) and coffee (*Coffea arabica*) with areas varying between the three districts (Table 2). While the district of Hawassa Zuria is oriented toward food crop production (maize, enset, and haricot bean (*Phaseolus vulgaris*)), Tula and Wondo Genet have more cash crops, such as khat and coffee. Households owned between two and three TLU and the sale of livestock constituted the third source of income in the three districts. The average milk production was about one litre/cow/day for the three districts and mostly destined to household consumption.

3.2. Drivers of change as perceived by farmers

The focus group discussions indicated that farmers perceived political regime shifts, climatic conditions, and pest and disease outbreaks as the main drivers of change in their farming systems. Before 1970, livestock diseases exterminated large numbers of cattle. The land use right policy (1974), which marked the end of a feudal system and gave landless people access to land, and the end of the communist regime (Derg) in 1991, were the two major national level political drivers of farming systems changes. Extreme weather conditions (hail, flood, and drought) periodically affected maize productivity. During dry years, locust and maize stemborer were reported as major maize pests. After the year 2000, governmental extension services started a campaign to inform the residents of the study area about improved farming practices and have provided subsidies for agricultural inputs (fertilizers and seeds). Currently, maize (the major staple food) productivity remains very variable and subject to climate hazards and input availability. Average number of members per household has been increasing due to a combined effect of polygamy and improved health access (Figure 2).

3.3. Farmers' responses: typology of farming system trajectories

Farmers delineated four farm types based on the farm size, the number of livestock, the variety of crops in the farm, the capacity of the household to send children to school, and the type of housing as criteria for classifying current farming systems and livelihoods (Appendix 1). Generally, three main livelihood strategies with three types of assets or activities contributing to livelihood strategies have been identified. The farmers' strategy consisting of accumulating assets from existing activities for moving into different activities that have higher and/or more stable returns is referred to as specialization or 'stepping out' strategy (Dorward et al., 2009). Consolidation or 'stepping up' strategy refers to an expansion of existing activities in order to increase production and income. Livelihood diversification is defined as the process by which rural families construct a diverse portfolio of activities and social support capabilities in order to survive and to improve their standards of living (Tittonell, 2014). Based on the cluster analysis, three main trajectories of farming systems change could be distinguished corresponding to three main strategies: 'consolidation' (type 1), 'diversification' (type 2), and 'specialisation' (type 3) (Appendix 2) representing respectively 39, 12, and 9 farmers out of the total of 60. Although these three trajectories differ in current production orientation, some trends in farm structural changes between the two time periods are common to them: (i) a decline in per capita land holding (with highest decrease for the diversification trajectory) and livestock numbers (with highest decrease for the specialization trajectory), (ii) an increase of cash crop production (with highest increase for the specialization trajectory) and in the proportion of food purchased by the household, and (iii) a decrease in non-cultivated land with a lesser extent for the consolidation trajectory (Figure 3, Appendix 3). Under the consolidation trajectory, the proportion of land dedicated to food crop production was maintained or increased, while it has decreased in the two other trajectories (with the highest decrease for the diversification trajectory). While many farmers were self-sufficient in food production at the time they started farming, they are now purchasing up to 70% of their food. The consolidation trajectory was found evenly distributed in the three districts with 15, 13 and 11 farmers out of the 60 in Hawassa Zuria, Tula, and Wondo Genet, respectively. However, the specialization trajectory was mainly found in Wondo Genet and Tula with respectively 9 and 4 farmers and only 1 farmer in Hawassa Zuria.

3.4. Current agricultural landscape composition

During the focus group discussion on land cover changes, farmers indicated that the land cover in the three districts was dominated by forest and grassland up to the early 1970s. The principal occupation of farmers was livestock rearing and only a limited area

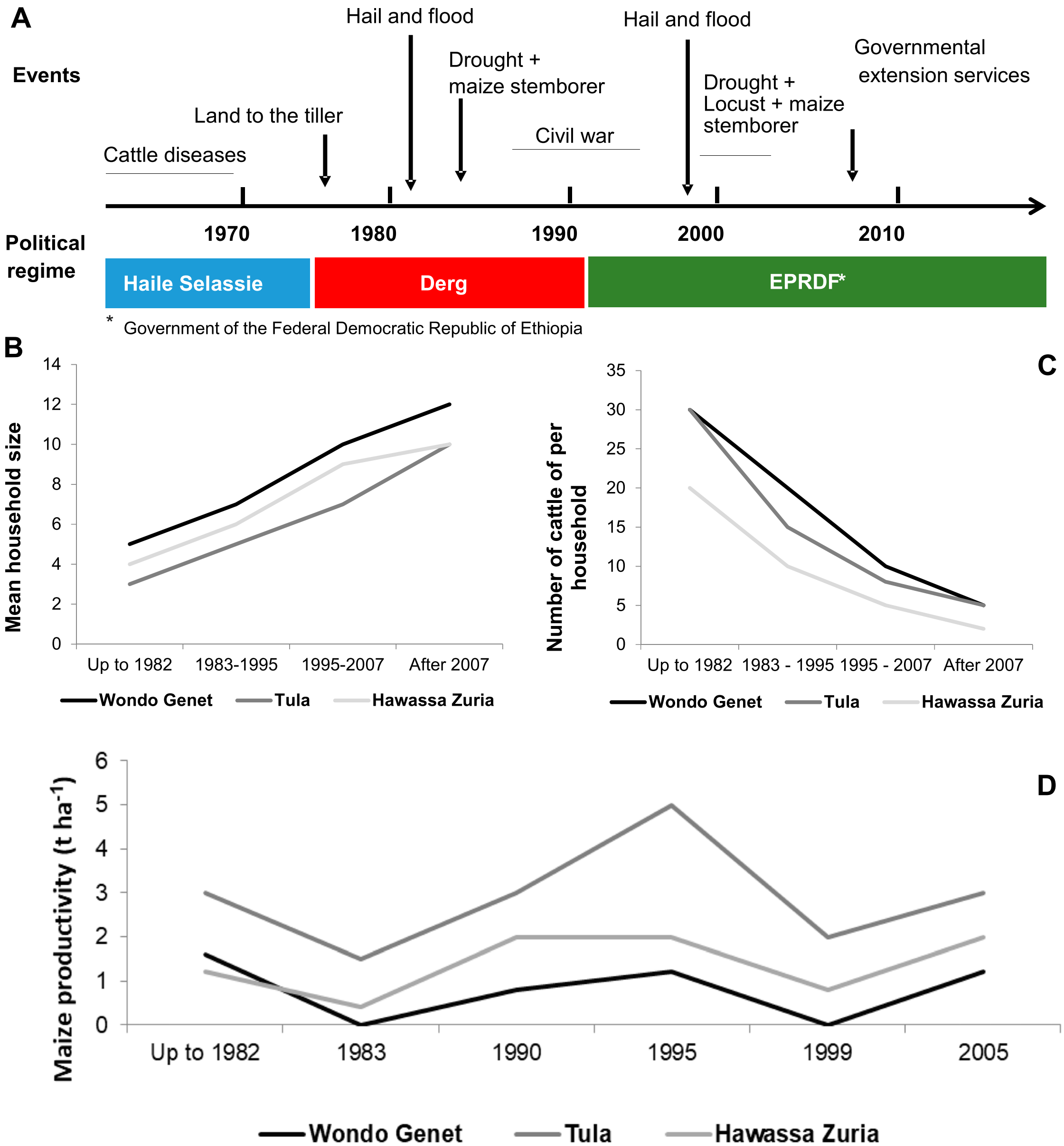

Figure 2. Timeline of historical drivers of change (A), number of people per household (B), number of cattle per household (C), and maize productivity (D) as per farmer's perception from 1970s to current situation ($n = 60$).

of the land was used for arable crops. From the late seventies to 2015, the area of cropland expanded and has become the main land cover in each district. Maize was the dominant crop in the 1980s covering 90%, 55%, and 65% of the arable land in Hawassa Zuria, Tula, and Wondo Genet, respectively (Figure 4 (D–F)). After 1990, in Hawassa Zuria, maize was progressively replaced by enset, haricot beans (generally intercropped with maize), and diverse home gardens (Figure 4(D)). In Tula, khat increased from less than 5% of the cropland in the 1980s to 30% in 2014, and enset decreased by about 10% along the same period (Figure 4(E)). In Wondo Genet, khat was not grown in the 1980s and covered 45% of the arable land in 2014, while enset decreased from 20% to 10% during the same period (Figure 4(F)). The land

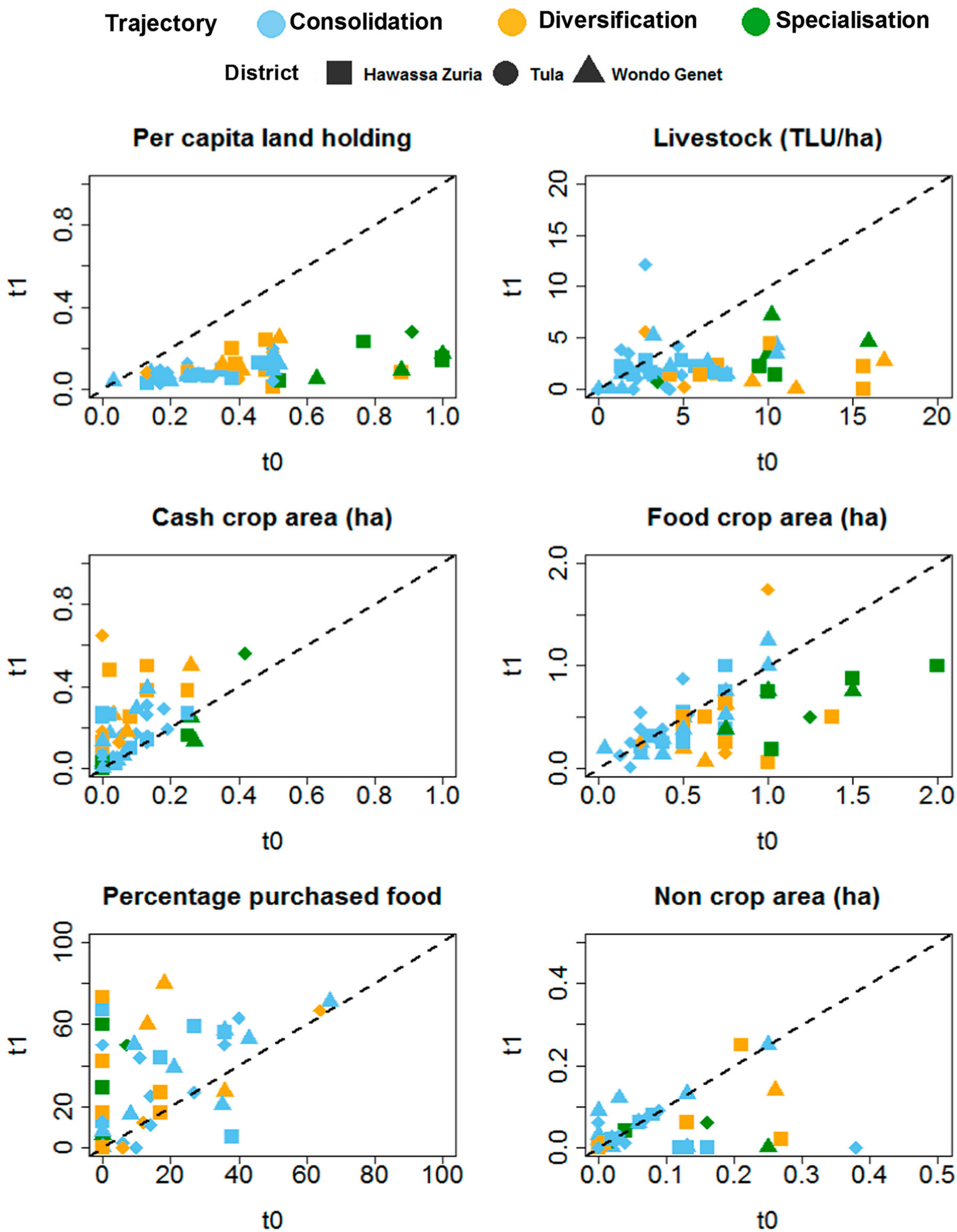

Figure 3. Per capita land holding (A), number of livestock (B), cash crop area (C) and food crop area (D) per farming system trajectory type, as well as percentage of purchased food (E), and area of non-cultivated land (F) at two time periods (year of settlement and 2015) per trajectory type (1, 2, 3).

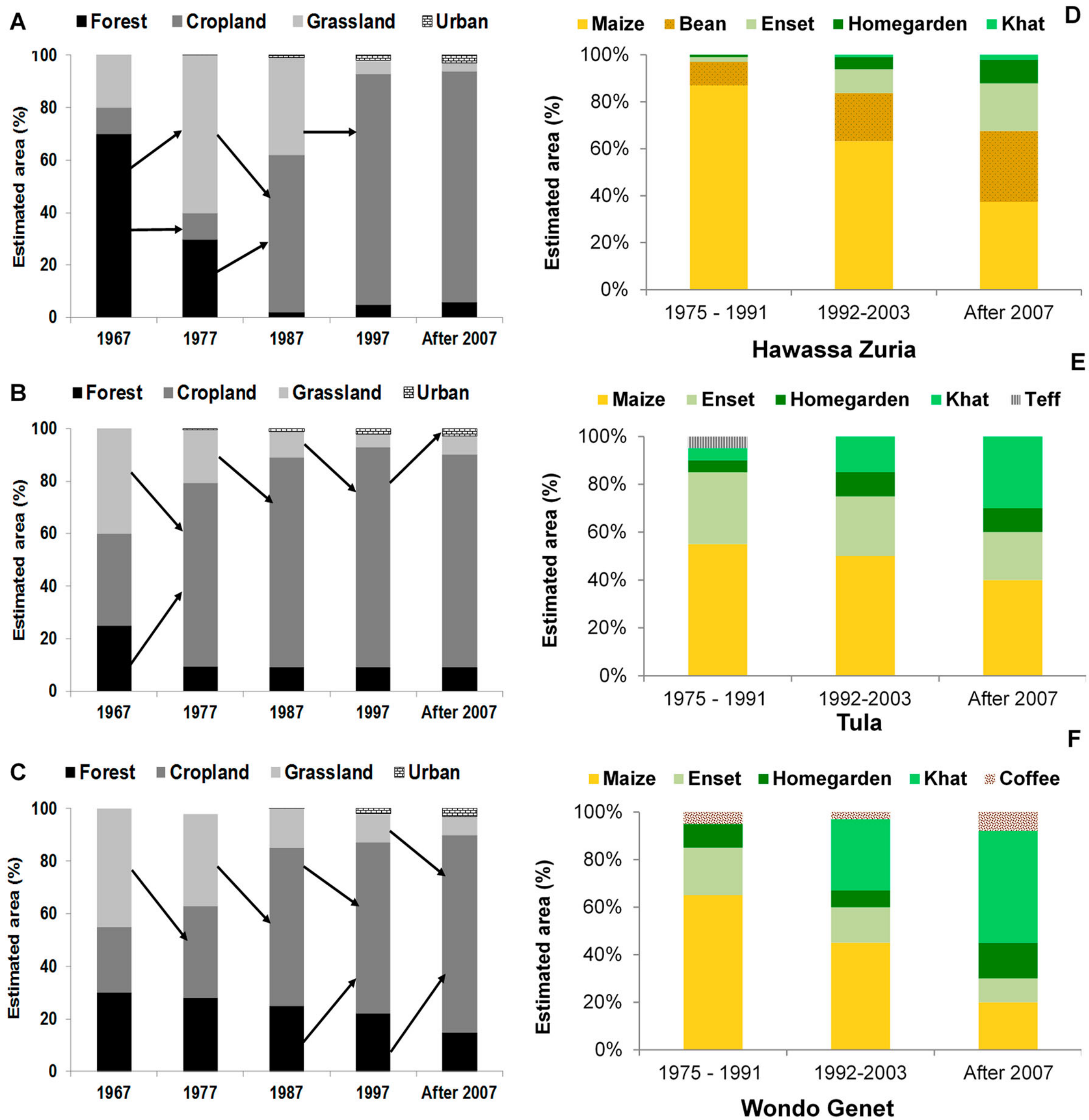

Figure 4. Farmers' perception of historical land cover changes from 1970s to the current situation for the three districts in Hawassa Zuria (A), Tula (B), Wondo Genet (C). Arrows indicate the shift of a land cover class; and farmers' perception of historical land use changes after the land use right reform in 1975 to current situation for the three districts in Hawassa Zuria (D), Tula (E), Wondo Genet (F).

cover change analysis with remote sensing confirmed these changes. The most pronounced changes involved an increase in the area of perennial crops and a decrease in the area of annual crops (mainly maize), grasslands, and bare soil in the whole study area between 1984 and 2014. Mixed croplands, perennial or annual, were relatively stable throughout the study period. The built-up area, covering the urban areas and roads, tripled over the same period (Figure 5(B)).

4. Discussion

We found that national level policies, extreme climatic events, biotic stress, population increase (due to the combined effects of migration and

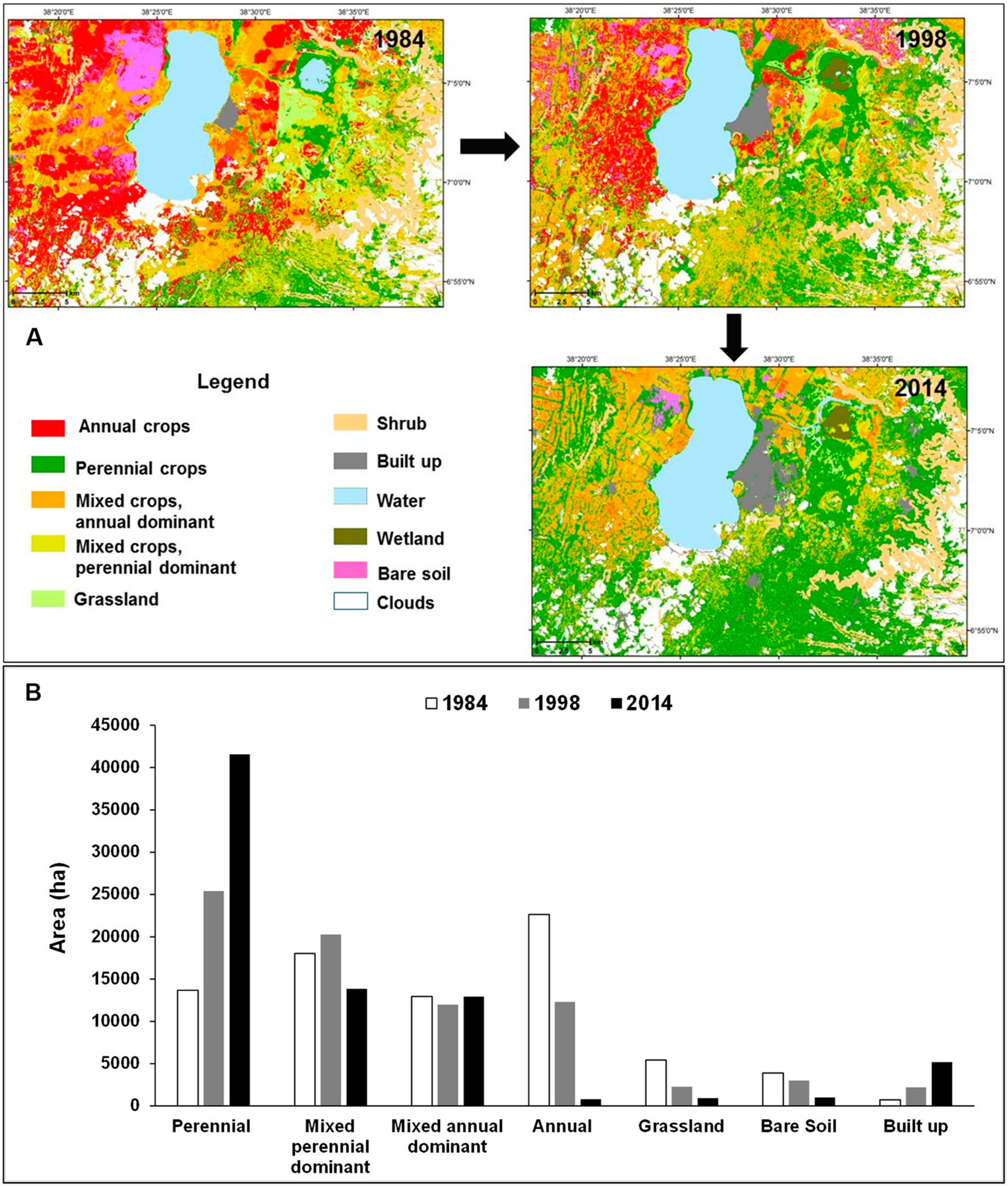

Figure 5. Quantitative analysis of land cover/land use changes using Landsat satellite images for 1984, 1998, and 2014.

natural increase), and urban expansion were major drivers of farming systems changes in the Hawassa area. At the local level, population growth, the expansion of urban areas, the biophysical conditions found in each district (in particular soil fertility (Kiflu & Beyene, 2013; Mellisse, Descheemaeker, Giller, Abebe, & van de Ven, 2018)) and the distance to markets influenced land cover/land use changes and farming systems. Per capita land and livestock numbers decreased for the three districts leading

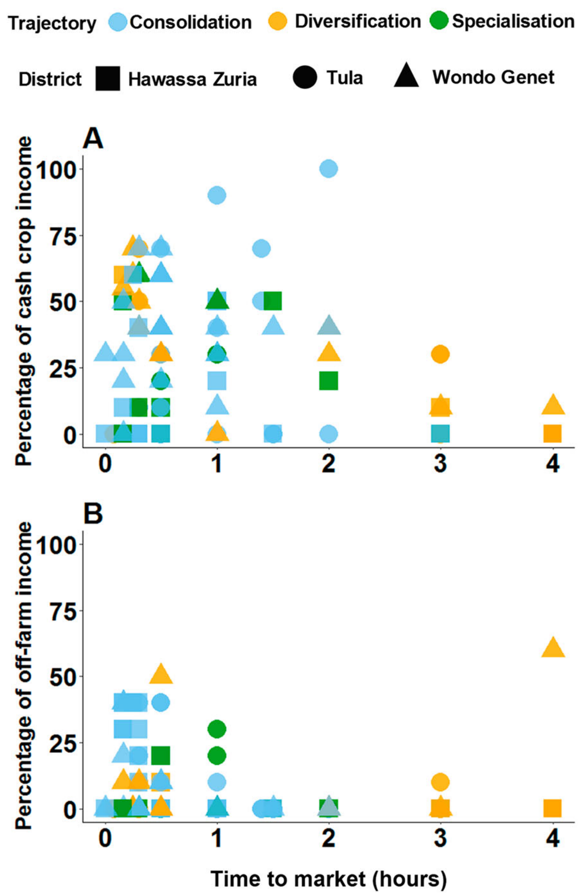

Figure 6. Percentage of cash crop income (A) and ratio of off-farm activity income (B) in relation to the time to reach the nearest market per trajectory.

to variable responses in farmers' livelihood strategies. Three trajectories of change of farming systems were identified: (1) consolidation and maintenance of farm size for food crop production and number of livestock with a slight increase in off-farm income, (2) diversification, with a slight increase in cash crop area and livestock, and (3) specialization, with the highest increase in cash crop area combined with reduced livestock numbers. These changes led to a more fragmented (a larger number of small size farms) and diverse landscape, with a more even distribution of crop types. Such fragmentation and diversification of the agricultural landscape has consequences for the provision of ecosystem services of local and global importance (Kremen & Merenlender, 2018; Lambin & Meyfroidt, 2010; Meshesha, Tsunekawa, Tsubo, Ali, & Haregeweyn, 2013; Newbold et al., 2015), as discussed in subsequent sections.

4.1. Current farming systems in Hawassa area

Current farming systems in the three districts of the Hawassa area are mixed crop-livestock systems with variable integration levels between the crop and livestock components. Although similar crop types were found in the three districts (enset, khat, maize, and common bean; coffee was only found in Tula and Wondo Genet), the average area allocation for those crops varied between the three districts. Hawassa Zuria remained predominantly oriented towards maize production, building on the historical State farms during the Derg period (cf. Figure 4(D)). However, the periodic failure in maize production due to the combined effects of poor rainfall (leading to increased pest issues, in particular maize stem-borers), and inadequate soil fertility management (Abebe & Feyisa, 2017) led farmers, with the support of local authorities, to convert part of their land to enset production. Enset, a drought-resistant crop with high cultural value for southern Ethiopia, ensures food for more than 15 million people (Abebe, Wiersum, & Bongers, 2009) and an essential livestock green feed resource during the dry season. Homegardens in southern Ethiopia are diverse systems where food and non-food crops are found (Abebe, Wiersum, Bongers, & Sterck, 2006; Lemessa & Legesse, 2018). Although small in extent, vegetables such as potatoes, cabbages, tomatoes, sweet potatoes, chilli peppers, and fruit trees (avocado, mango, and banana) were found. These crops were mainly managed by women and play an important role in the dietary diversity of the household and in filling the food gap during the dry season (Calvet-Mir et al., 2016; Gbedomon et al., 2017; Lemessa & Legesse, 2018; Mellisse et al., 2018). In terms of livestock management, next to free ranging, roadside grazing, and/or zero grazing practices, farmers also practise dry-season transhumance to Cheleleka wetlands in the northeast of the Hawassa area where communal grazing lands are available.

4.2. Drivers of change of farming systems

Farmers' perception of drivers of change gave a strong focus on historical political regime changes, abiotic constraints (climate variability and extreme weather events, such as erratic rainfall, hail, and drought episodes), and biotic constraints (animal disease and pest outbreaks). These drivers of land cover/land use change are similar to those reported at national or even international level across Africa (Reid et al., 2000). In addition, although it has not been mentioned directly by farmers, the increasing relative price of cash crops in relation of food crops has been a driver of the shift of the production from food to cash crops. In fact, the revenue per ha from khat can be 15 (Dessie, 2013) to 16 times (Mellisse et al., 2018) higher than maize or teff, and three (Mellisse et al., 2018) to four times higher than coffee (Dessie, 2013). Farmers reported an increased household size over the studied period, but they did not mention a strong impact on household food security. However, in Tula and Hawassa Zuria some farmers indicated that their production did not allow them to meet the household's need. This is confirmed by the national safety net programme running in those districts (Sharp, Brown, & Teshome, 2006), which provide food in exchange for labour for the community or the municipality. This is a surprising phenomenon since Tula is the closest of the three districts to Hawassa town, an important khat market, implying that off-farm opportunities are high. However, only about 10% of farmers in Tula indicated off-farm activity as their primary source of cash. The proximity to Hawassa town may actually represent a threat for some farmers. Indeed, with an increasing cost of land in Hawassa town and an on-going plan to transform Tula into Hawassa's sub-city, middle men are approaching farmers to convince them to sell all or part of their land with the intend of purchasing it at an extremely low price compared to the potential (high) value the land would fetch as urban ground (Gebeyehu Admasu, 2015). This is an uncontrolled land market even though land in Ethiopia is state-owned and not meant to be traded; however, improvements such as housing, corrals, trees and land titles can be traded. However, once the land is acquired by a middleman, whenever any infrastructure is built on it, it becomes legally more difficult for government authorities to reclaim the property. This process is also taking place in the other two districts, thus influencing the land use changes in the overall Hawassa area (Gebeyehu Admasu, 2015).

4.3. Typology of household trajectories

Three trajectories of farmers' adaptation strategies to decreasing land size and livestock numbers were observed: consolidation (65% of households), diversification (15% of households) and specialization (20% of households). Most farmers followed the consolidation trajectory maintaining food crop production and livestock. In the study area, sharing harvest with less-endowed farmers in exchange for labour is a common practice ('shared cropping'), which might benefit the farmers grouped under the diversification trajectory. Indeed, the diversification group has the highest reduction in farmland size with low income from cash crops. Farmers who engaged in the specialization trajectory (mostly in Wondo Genet and Tula) were able to take this direction due to a combined effect of market proximity (Figure 6(A)) and biophysical potential for khat and coffee production (Mellisse, van de Ven, Giller, & Descheemaeker, 2017). In addition, the production of khat has only been tolerated since the end of the Derg regime (previously not encouraged). The observed shift in favour of this high-profit cash crop has been seen in other regions of Ethiopia that were mostly coffee-oriented (Mellisse et al., 2017). Both coffee and khat are important export commodities for Ethiopia. In the last 15 years, khat gained popularity among smallholders over coffee production due to the high and constant market demand for this stimulant produce. In addition, khat can be harvested two to three times per year, is relatively quick to establish (one to two years) and is less demanding in management or input compared to annual crops. These specificities make khat a very competitive cash crop over coffee production, although traditional subsistence food crops, such as maize and beans, can still be important sources of income (i.e. in Hawassa Zuria, see Table 2). The time to reach the market plays a role on the income from off-farm work opportunities (Figure 6(B)): the majority of farmers engaged in off-farm activities are within an hour of the nearest market.

4.4. Consequences for landscapes

From the 1970s to the 1980s the land cover/land use changes in the Hawassa area consisted of the replacement of forest and grasslands areas by croplands (Figure 5) as reported by Negash and Niehof (2004) and Reid et al. (2000). Landscape changes included a reduction in field sizes and an increase of perennial crops (khat and enset) at the expense of annual crops, grasslands, and bare soil. The main consequences of the landscape changes are habitat loss for wildlife and a decrease in water availability (Dessie & Kinlund, 2016; Shewangizaw & Michael, 2010). In Wondo Genet, the expansion of the khat resulted in a decline of natural forests and an associated forest fragmentation in major khat producing areas, a decline in food crop production, and soil erosion from steep land cultivation (Reynolds, Farley, & Huber, 2010). Farmers reported that attacks on their maize fields by baboons were one of the reasons they decreased maize production. The decrease in water availability has been reported by previous studies which investigated the effect of land cover/land use change on the hydraulic regime and water volume of Lake Hawassa (Abebe et al., 2018; Shewangizaw & Michael, 2010). A remarkable feature on the land classification map (Figure 5(A)), is the vanishing of what used to be the Lake Cheleleka in the northeast of Hawassa area, which is now a wetland. In Hawassa Zuria, the decline of forest and current continuous removal of trees and shrubs for firewood is leading to major flood and gully erosion (Gebretsadik, 2014). However, the higher diversity and complexity of Wondo Genet could have a beneficial effect on the biocontrol of major pests (Kebede et al., 2018).

5. Conclusions

Farming systems in the Hawassa area have been subjected to dynamic and rapid changes over the last 30 years. These changes were due to a combined effect of national level policies, regional urban expansion, population growth, extreme climatic conditions, and households' livelihood assets. In addition, other drivers, such as the informal and lucrative land market associated with the proximity of Hawassa town, have had a strong influence on land use changes. Diversification, the intensification of current cropland through mixed-cropping and intercropping, and the orientation towards high value cash crops are among the strategies adopted by farmers to cope with reduced availability of cropland. These socio-ecological changes associated with livelihood strategies and household trajectories resulted in changes in landscape structure and composition, specifically in fragmentation and diversification, which may have implications for the provision of ecosystem services including, food provisioning. The decrease in forest and continuous cropping with the associated loss of soil fertility is already impacting current productivity and might have a severe negative impact on the future agricultural production potential of the area (Dessie & Christiansson, 2008). A better understanding of interlinkages and trade-offs among ecosystem services and the spatial scales at which the services are generated, used, and interact is needed in order to successfully inform future land use policies. More concretely, one priority should be the investment in natural capital in the form of reforestation, whatever the future rural or urban land use orientation of the Hawassa area would be. This will require an important coordination between the institutions involved in the governance of the overall landscape (e.g. agriculture, environment ministries, urban expansion planners, and farmer associations). It would be valuable to also engage youth associations in these efforts, as the lack of access to land and a general disinterest in farming is already pushing many young people towards urban areas.

Disclosure statement

No potential conflict of interest was reported by the authors.

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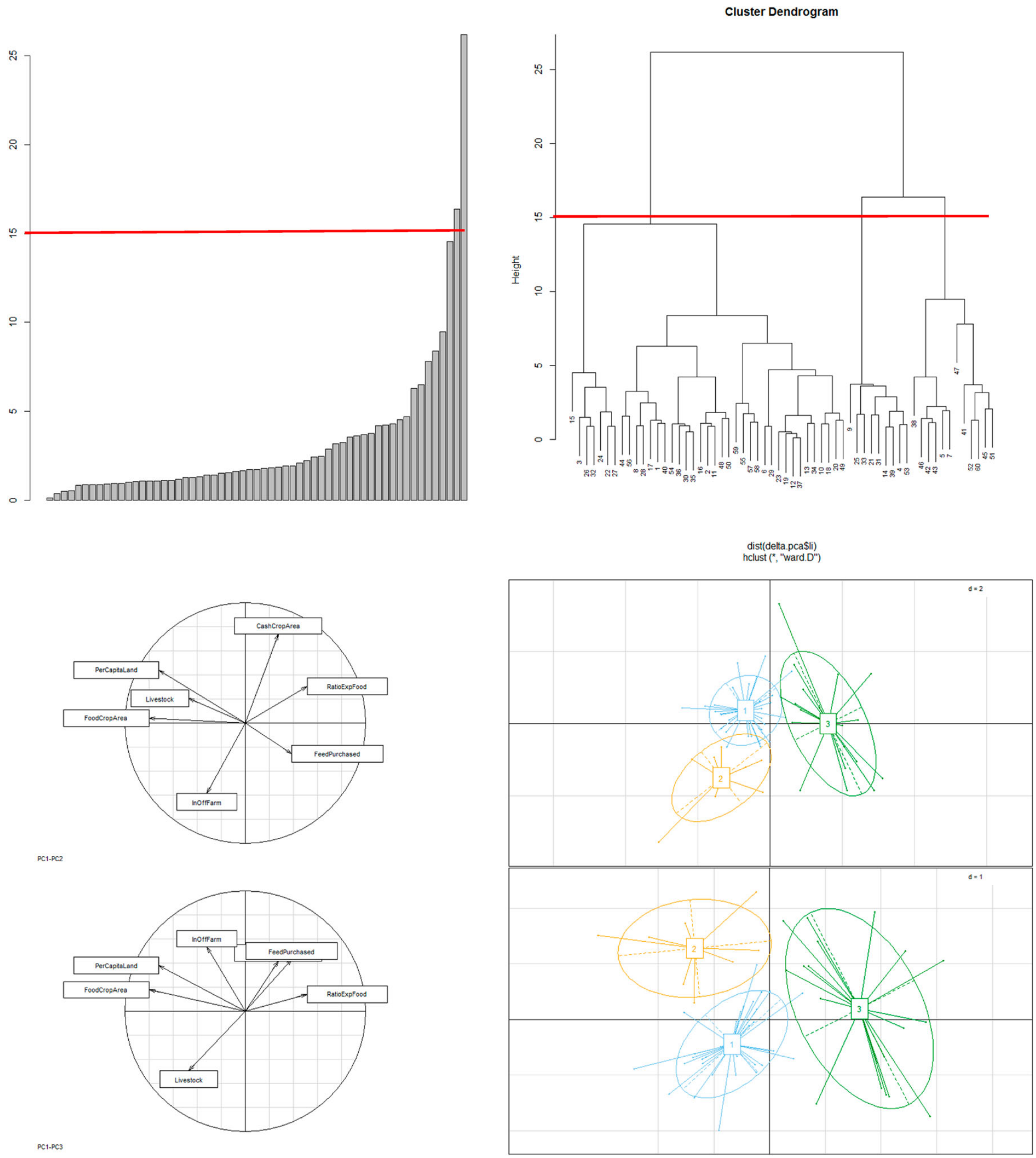
Appendices

Appendix 1. Self-categorization criteria obtained from the focus group discussions

Criteria	Description
Selected by farmers in the three districts	
Food security	Food self-sufficient family with surplus for market sale (1); Food self-sufficient family (2); Partially food self-sufficient family with off-farm activity (3); Food insecure family, dependent on external support (4)
Livestock size	More than ten cattle, small ruminants with transporting animals (1); pair of oxen, cows, small ruminants (2); single or no oxen, cow with /out small ruminants (3); no livestock (4)
Arable land size	>1 ha (1); >0.5 ha (2); <0.5 ha (3); <0.25 (4) ha or landless
Use of agricultural technologies	Use of fertilizers and improved seeds regularly (1); using inputs occasionally (2) and using inputs very occasionally (3); can't afford purchasing inputs (4)
Selected by farmers in two districts (Wondo Genet and Tula)	
Home garden crop diversity	Produce diverse food and cash crops (1); produce different crops (2); focusing on food crops (maize, enset) (3)
Irrigation	Own water pump or point and produce different crops three times per annum (1); hire or borrow water pump and produce different crops (2); use furrow or hand spray, have no access to irrigation water (3)
Educating children	Can send children to private schools (1); can send children to public school (2); send children to public school but do not fulfil all needs (3); unable to send children to school (4)
Selected by farmers in one of the three districts (Tula)	
Number of coffee trees	300–400 coffee trees (1); 30–40 coffee trees (2); 5–7 coffee trees (3); no coffee tree (4)
Maize productivity	Can harvest up to 60 quintals per ha (1); up to 15 quintals per ha (2) and (3); up to 10 quintals per ha (4)
Housing type	Can afford housing in urban area to rent out or live in (1); corrugated roof housing (2) and (3); thatched roof housing (4)

Appendix 2. Principal component analysis of trajectories of change of farming systems: three types of trajectories can be observed: consolidation (type 1), diversification (type 2), and specialization (type 3).



Appendix 3. Changes in farm structure and production orientation of the three trajectories (consolidation, diversification, and specialization).