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Family farming: the case of Ethiopia

1. *Introduction*

According to Lowder *et al.* (2014), 570 million farms exist around the world. About 500 million of these farms are managed by individual or a family and they produce 80% of the world's food required to feed 7 billion people (FAO, 2014a). These farms involve 2.6 billion people worldwide, making it the world's top employer with 40% of the total active population engaged in farming. The majority (72%) of family farms are smaller than one hectare, while 6% are bigger than 5 ha (FAO 2014b).

It is thus clear how family farming plays a prominent role in ensuring global food security, poverty reduction and environmental sustainability. Moreover, family farming is key to sustainable agricultural production as it conserves biodiversity and produces valuable ecosystem services. Thus family farms are recognized as part of the solution to the hunger problem and 2014 was declared by UN as the International Year of Family Farming (IYFF). According to FAO (2014a), family farmers in Brazil, USA and Fiji provided 40, 84 and 84% of crop production, respectively. Similarly, 80% of all farms in Africa are family farms and small scale farmers produce 80% of the national food supply in the region (Bioversity International, 2014). This indicates that family farming is the most dominant form of agriculture in both developed and developing countries. Small scale farmers have contributed to evolutionary services of biodiversity by allowing crops to evolve and adapt to changing climatic conditions and diversify them to reduce vulnerability.

Ethiopia is one of the countries which are dependent upon agriculture. It is a land locked country in the horn of Africa sharing borders with Eritrea in the North, the Sudan and South Sudan in the west, Kenya in the south and Somalia and Dji-

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Fig. 1. Map of Federal Democratic Republic of Ethiopia and Regional States.

bouti in in the east (Figure 1). It is geographically located within the tropics, between 3°24` and 14°53` N; and 32°42` and 48°12` E (Alemayehu, 2006). Ethiopia follows a federal parliamentary government system with nine regional states, one city council and one city administration. It is a land of ethnical, cultural, biological and agroecological diversity in an area of 1.14 million km^2. In fact there are more than 80 ethnic groups with their own language together with 200 dialects, culture and traditions. The major religions are Christianity (63%), Islam (34%) and traditional faiths and others (3%). The country's per capita yearly income in 2013 was 550 USD with a GDP of 47.53 billion USD. With 96.5 million people (WB, 2014), Ethiopia is the second most populous country in Africa and 80% of the population lives in rural areas, the majority engaged in low-input low-output agricultural activity (Awulachew *et al*., 2007).

Ethiopia is also considered the cradle of human kind after the discovery of Lucy, a.k.a Dinkinesh in Amharic, who walked on our planet 3.2 million years ago. Lucy was found in the north eastern part of Ethiopia in 1974. Other prominent archeological findings were discovered since then around the same region. The coun-

try has also great importance in view of agricultural biodiversity as a host of important gene pools, such as resistant genes in cereals. Ethiopia is the center of origin and diversity for many important plant species which have nutritional and economical significance, such as coffee and teff. Therefore, Ethiopia occupies a significance place in archeological, human evolution and plant diversity studies. Moreover, there are 8 cultural and 1 natural world heritage sites recognized by UNESCO which are tourist destinations (UNESCO, 2015).Agriculture contributes greatly to Ethiopian economy. The contribution to Ethiopian GDP reaches up to 40%. Therefore, increasing productivity in smallholder agriculture is the Government's top priority. This paper tries to look into the status and contribution of agriculture and family farming in Ethiopia.

2. *Topography, climate and natural resources*

Ethiopian is characterized by a large geographical diversity with high and rugged mountains, plateaus, valleys, deep gorges and rolling plains (Figure 2). The altitudinal difference is very wide, ranging from 115 meters below sea level at Danakil (Dalol) depression to the 4,620 meter above sea level of mount Ras Dashen which is located in Semen Mountains national park. Most of the highest mountains are home for endemic birds and wild animals, like Walia Ibex and Red Fox (Figure 3).

On top of highland areas, the largest area of continuous plateau is found which constitutes the central part of the country. The central mountain and plateau part of the country is divided in two by the rift valley (the east African rift) that runs from north east to south west of Ethiopia. The rift valley is part of the Great Rift Valley, which stretches from the Middle East in the north to Madagascar in the south.

Lowlands make up nearly 61-65% of the land-mass, and are the major pastoralist and agro-pastoralist areas. These topographic conditions, together with altitudinal differences, result in great variation of climate, soil and vegetation (Alemayehu 2006).

Temperature and rainfall

Temperature and rainfall are the most important climatic factors for agricultural production in Ethiopia. Temperatures range from the mean annual of 34.5°C in the Danakil Depression, to the lower temperatures below zero in the mountains (>3,500 m a.s.l.) with a mean <0°C. However, beyond these extremes, the mean annual temperatures are between 10° and 20°C.

Rainfall in Ethiopia is torrential and erratic in pattern and distribution. Generally, average annual rainfall of areas above 1,500 m a.s.l. exceeds 900 mm. In the lowlands (below 1,500 m a.s.l.) rainfall is erratic and averages below 600 mm. Despite variable rainfall, which makes agricultural planning difficult, a substantial proportion of the country receives enough rain allowing rain fed crop production. Based on rainfall distribution and pattern, the country has been classified as depicted in Figure 4A and 4B. Two rainfall patterns exist in Ethiopia. They are unimodal and

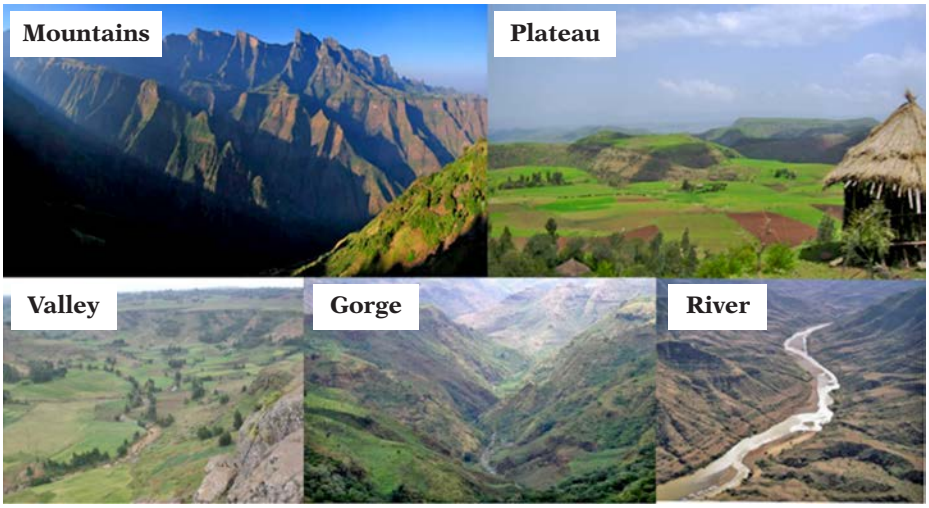


Fig. 2. Topography of Ethiopia.

bimodal rainfall pattern. The bimodal pattern has one long rainy season that begins around June/July and a short rainy season which starts around March/April. In the unimodal areas, there is no rain in March/April.

The combination of temperature and rainfall together with soil properties, the length of crop growing period varies across the country. The country has been classified into three growing periods as depicted in the map (Figure 4C).

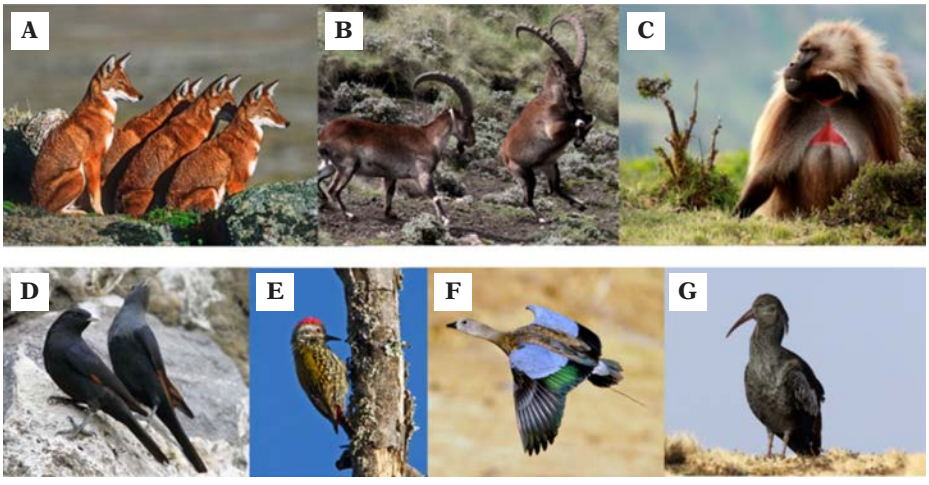


Fig. 3. Endemic wild animals and Birds: A) Red Fox, B) Walia Ibex, C) Gelada Baboon, D) White-billed Starling, E) Abyssinian Woodpecker, F) Blue-winged Goose and G) Wattled Ibris.

Soil type

The wide ranges of topographic and climatic factors, parent material and land use resulted in extreme variability of soils. About 19 soil types are identified throughout the country. However, a few are important for agriculture. A large proportion of the country is covered by lithosols, nitosols, cambisol, regosols, vertisols and fluvisols in order of their importance and total land coverage (Alemayehu, 2006, Dubale, 2001). The soils that are important for cultivation cover a total area of about 40 million hectares. Nitosols, cambisols and vertisols cover 23, 19, and 18% of arable lands, respectively. Nitosols are highly weathered, acidic with high P sequestration, and are well drained. The problem with nitosols is that they are vulnerable to erosion and leaching. On the other hand, vertisols are more fertile as compared to other major soil types. The main constraints of this soil type is water logging during wet season and cracking during dry season, which make cultivation difficult for both animal drawn plowing as well as tractor operation. Vertisols are found in the main agriculturally active regions, such as central highlands, southern, eastern and western parts of the country. Most soils in the highland are deficient in important nutrients and require fertilizers to sustain crop productivity (Alemayehu, 2006).

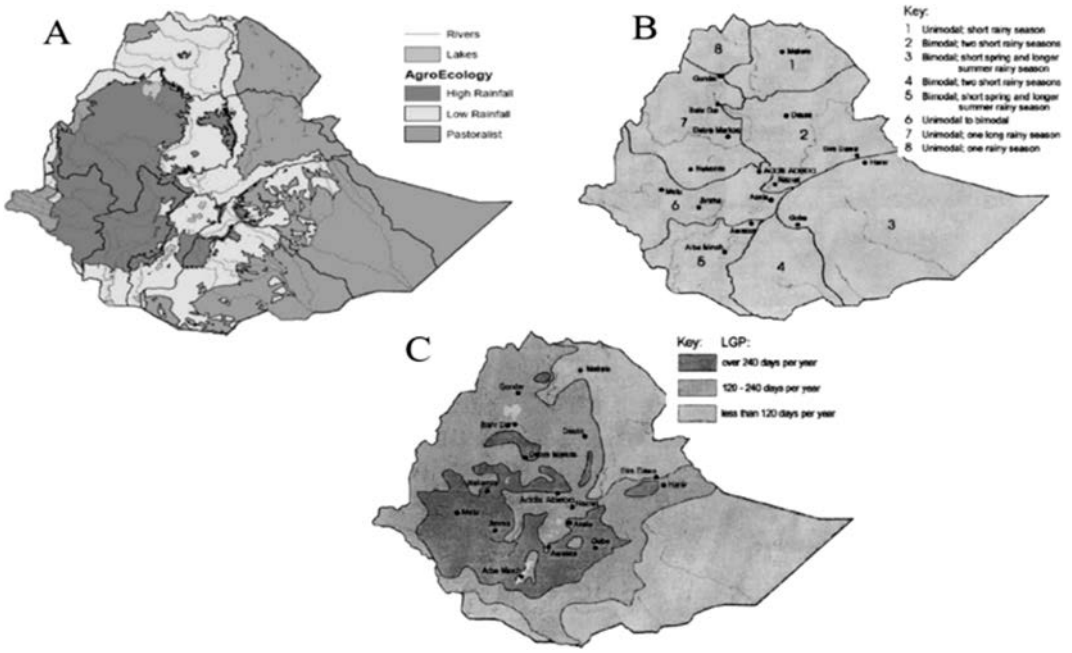


Fig. 4. A) Rainfall potential areas of Ethiopia, B) Rainfall Pattern in Ethiopia, C) Length of Growing periods in Ethiopia (LGP) Source A USAID, 2001 B and C (Hurni, 1998).

Water resources

Ethiopia is considered as water tower of East Africa because of a number of water bodies which start from the highlands and flow to different directions, creating 12 river basin across the country (Figure 5 and Table 1) (Awulachew *et al*., 2007). There are 10 major rivers and around 15 lakes (10 of them are in the rift valley) which have irrigation and fishing potential (Awulachew *et al*., 2007, Kebede *et al*., 1994). The annual runoff volume is 122 billion m^3 water with an estimated 2.6 to 6.5 billion m^3 of ground water potential. Almost all major rivers flows towards neighboring countries and as far as Egypt and joining the Mediterranean Sea. However, due to lack of large scale irrigation scheme, water storage infrastructures as well as spatial and temporal variation in rainfall, the country has not been able to utilize this potential to the fullest thus far, although there are some efforts to utilize trans-border rivers for the generation of hydroelectric power (Table 1) (Awulachew *et al*., 2007).

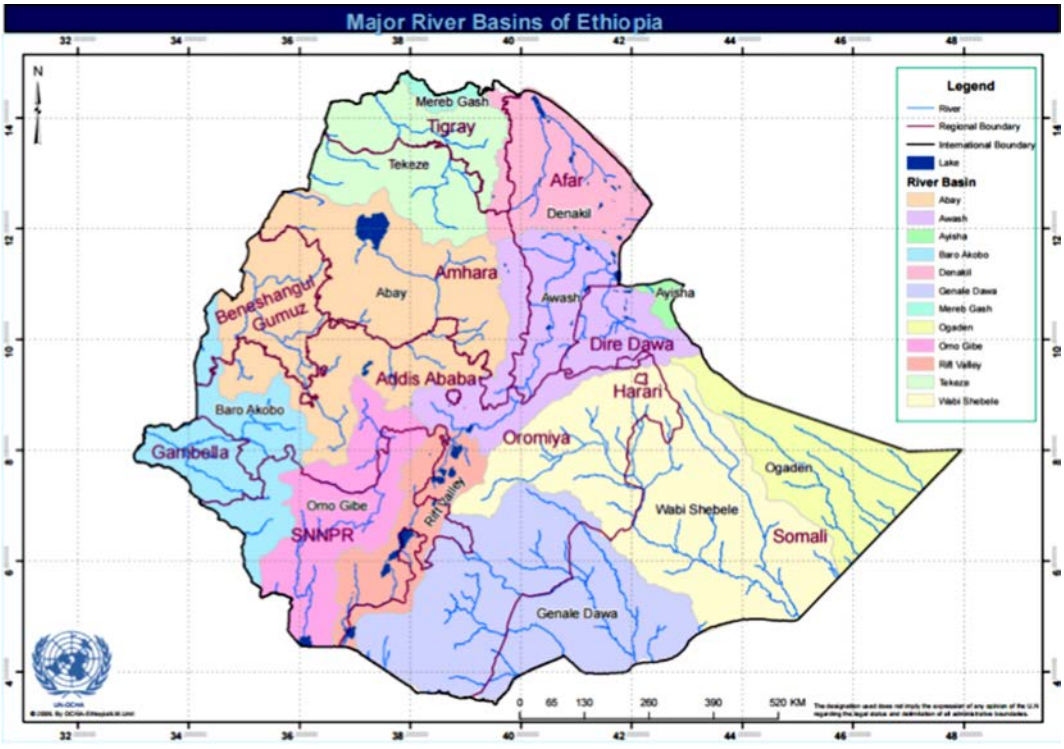


Fig. 5. Map of Major River Basin of Ethiopia.

Table 1. Ethiopian River basins and their Irrigation and hydroelectric power potential.

River Basin	Area (Km^2)	Runoff (Bm^3)	Potential Irrigable Land (ha)	Gross Hydro-electric potential Gwh/year	Estimated ground water potential (Bm^3)
Tekeze	82,350	8.2	83,368	5,980	0.20
Abbay	199,812	54.8	815,581	78,820	1.80
Baro-Akobo	75,912	23.6	1.019,523	13,765	0.28 0.13Recharge/year
Omo-Ghibe	79,000	16.6	67,928	36,560	0.42 (.10)Rech/yr
Rift Valley	52,739	5.6	139,300	800	0.10
Mereb	5,900	0.65	67,560	–	0.05
Afar/Denakil	74,002	0.86	158,776	–	–
Awash	112,696	4.9	134,121	4,470	0.14
Aysha	2,223	–		–	–
Ogaden	77,121	–		–	–
Wabi-Shebelle*	202,697	3.16	237,905	5,440	0.07
Genale-Sawa	171,042	5.88	1.074,720	9,270	0.14
Total	1.135,494	124.25	3.798,782	155,102	2.86

3. *Ethiopian Agro-Ecological Zones (AEZ)*

Ethiopia is endowed with diverse agro-ecological zones that differ in rainfall patterns, temperature, soil types, topography and altitude. Blanket agricultural technology development and recommendation do not fit to the existing diverse climatic condition, as there is a huge variation in farming systems, population density and socio-economic conditions in the different agro-ecological zones (Alemu *et al*., 2009). In order to bring and facilitate agricultural and socio-economic development across the country, research and development activities should consider these variations. Appropriate agro-ecological zonation help governmental and non-governmental organizations to identify problems and plan appropriate developmental strategies and technologies to each agro-ecological zone. Agro-ecological zonation can be defined as a spatial classification of the landscape into area units with «similar» agricultural and ecological characteristics (Hurni, 1998).

Ethiopian agro-ecological zones have been characterized in different ways based on several factors and depending on the objective of the classification. They have been classified based on rainfall patterns, length of growing season, temperature and rainfall amount (Figure 4). However, the two most known classifications are traditional and modern AEZ. Traditional AEZ considers temperature and altitude as basic factors to classify the agro-ecology. There are 6 different zones based on traditional classification (Table 2). However, rainfall amount and its distribution is also important in this traditional classification.

Table 2. Traditional Agro-ecological Zones and altitudinal ranges of selected crops.

Meters above sea level		Annual rainfall (mm)	
	<900	900-1,400	>1,400
More than 3,700			High *wurch* (no crops)
3,700-3,200		Moist *wurch* (barley)	Wet *wurch* (barley)
3,200-2,300		Moist *dega* (barley, wheat, pulses)	Wet *dega* (barley, wheat, pulses, oilseeds)
2,300-1,500	Dry *weyna dega* (wheat, teff, maize)	Moist *weyna dega* (maize, sorghum, teff, wheat, oilseeds, barley, *enset*)	Wet *weyna dega* (teff, maize, *enset*, oilsseds, barley
1,500-500	Dry *kolla* (sorghum, teff)	Moist *kolla* (sorghum, teff, pulses, oilseeds)	
Less than 500	*Bereha* (only irrigated crops)		

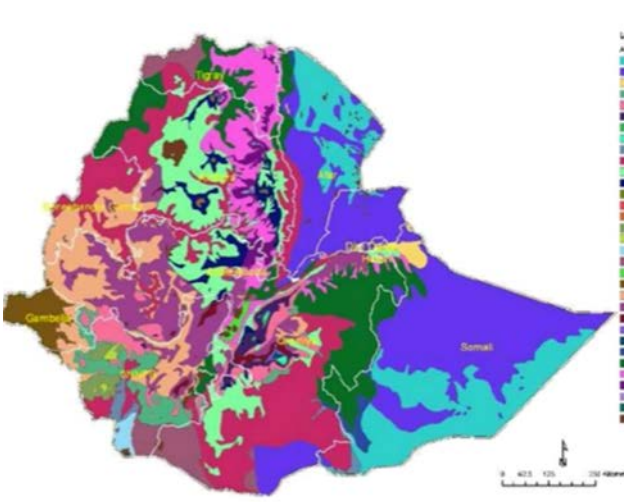
Source: Dorosh *et al*., 2013.

Because of the diverse nature of climatic, soil and topographic condition of the country, traditional AEZ is not enough in order to develop and implement several agricultural and socio-economic developmental activities. As a result a more comprehensive way of classification has been developed by the Ministry of Agriculture and Ethiopian Agricultural Research Organization (EARO) in 2000. It is referred as modern AEZ classification.

In the modern classification, the basic ecological elements of climate, physiography, soils, vegetation, farming system, length of growing period and animal production are utilized. This elaborated classification is to suit the country's diverse but unique natural and cultural diversity. A total of 32 major AEZ are identified based on homogeneity in terms of climate, physiography, soils, vegetation, land use, farming system and animal production (Figure 6). According to this classification, about 51% of the total land area of the country is under arid, semi-arid and sub-moist zones (Work *et al*., 2012)

4. *Current state of Agriculture in Ethiopia*

Ethiopia is heavily dependent on agriculture for its development. The agricultural sector plays a central role in the economy development of the nation. It is mainly a rain fed, low-input low-out put subsistence farming agriculture. With a total area of about 1.14 million km^2 and about 51.3 million hectares of arable land, Ethiopia has a tremendous potential for agricultural development. However, only



No.	Major agro-ecological zones (MAEZs)		the country
1	Arid	Hot arid lowland plains (A1)	10.87
2		Warm arid lowlands (A2)	19.71
3		Tepid arid mid highlands (A3)	0.43
4	Semi-arid	Hot semi-arid lowlands (SA1)	0.43
5		Warm semi-arid lowlands (SA2)	2.87
6		Tepid semi-arid mid highlands (SA3)	0.21
7	Sub-moist	Hot sub-moist lowlands (SM1)	0.56
8		Warm sub-moist lowlands (SM2)	9.60
9		Tepid sub-moist mid highlands (SM3)	5.21
10		Cool sub-moist mid highlands (SM4)	1.21
11		Cold sub-moist mid highlands (SM5)	0.10
12		Very cold sub-moist mid highlands (SM6)	0.02
13	Moist	Hot moist lowlands (M1)	0.65
14		Warm moist lowlands (M2)	15.12
15		Tepid moist mid highlands (M3)	8.03
16		Cool moist mid highlands (M4)	1.73
17		Cold moist sub-afro-alpine to afro-alpine (M5)	0.10
18		Very cold most sub-afro-alpine to afro-alpine (M6)	0.01
19	Sub-humid	Hot sub-humid lowlands (SH1)	1.76
20		Warm sub-humid lowlands (SH2)	7.10
21		Tepid sub-humid mid highlands (SH3)	6.63
22		Cool sub-humid mid highlands (SH4)	0.53
23		Cold sub-humid sub-afro-alpine to afro-alpine (SH5)	0.10
24		Very cold sub-humid sub-afro-alpine to afro-alpine (SH6)	0.04
25	Humid	Warm humid lowlands (H2)	2.32
26		Tepid humid mid highlands (H3)	2.79
27		Cool humid mid highlands (H4)	0.94
28		Cold humid sub-afro-alpine to afro-alpine (H5)	0.10
29		Very cold humid sub-afro-alpine (H6)	0.04
30	Per-humid	Hot per-humid lowlands (PH1)	0.04
31		Warm per-humid lowlands (PH2)	0.76
32		Tepid per-humid mid highland (PH3)	0.13

Fig. 6. Modern Agro Ecological zones of Ethiopia.

about 11.7 million hectares of land are currently being cultivated, just over 20% of the total arable area (MoARD, 2010). About 80-85% of the people are employed in agricultural activities. The sector contributes about 43% of total GDP and 90% of exports. Crops contributes 60% of the agricultural GDP while livestock and forestry producing 30% and 7%, respectively.

Crop production

In terms of cultivated areas, cereals are predominant (84.55%) followed by pulses (11.13%) and others (4.32%). According to the 10-year average (2003 to 2012), 95% of the total cereal production area had been covered by five crops: teff (*Eragrostis tef*) (28.4%), maize (20%), sorghum (18.2%), wheat (16.8%) and barley (11.7%) (Table 3). These same crops contribute to the top five productive cereals in terms of total harvest (Figure 7). However, crops such as pulses e.g. chickpea, beans, peas; oil crops e.g. sunflower, safflower, rape, noug (*Guizotia abyssinica*), groundnut; and root and plantation crops e.g. potato, sweet potato, yam, cassava, «enset» (*Ensete ventricosum*), and sugar cane have great food and industrial value (MoARD, 2010, Alemayehu, 2006).

Livestock Production

Ethiopia's livestock population is the first in Africa, with cattle, sheep and goats dominating the livestock population (Figure 8). About 70% of cattle and sheep and 30% of goats are raised in the highlands, whereas all camels are in the lowlands. Farm animals support the farming activity by providing animal draught power for

Table 3. Distribution of Area Harvested for Primary Crops (ha) from 2003 to 2012.

	Production Years											
Crop	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Average	%
Teff	1989068	2135553	2246017	2404674	2565155	2481333	2588661	2761190	2731112	2730273	2463304	28.4
Barley	920127	1095436	997868	1019314	984943	977757	1129112	1046555	948107.4	1018753	1013797	11.7
Wheat	1098907	1398215	1459540	1473917	1424719	1453817	1683565	1553240	1437485	1627647	1461105	16.8
Maize	1367115	1392916	1526125	1694522	1767389	1768122	1772253	1963180	2054724	2013045	1731939	20
Sorghum	1283654	1253620	1468070	1464318	1533537	1615297	1618677	1897734	1923717	1711485	1577011	18.2
Millet	304758	312931	333029	374072	399268	408098	368999	408110.3	432561	431506.9	377333.3	4.3
Oats	30048	45131	44401	32798	30556	30605	24018	30858.76	30568.39	26514.1	32549.83	0.4
Rice	..	..	6241	..	24434	35088	47739	29866.16	30649.3	41811.25	30832.67	0.4
Total	6993677	7633802	8081291	8463615	8730001	8770117	9233024	9690734	9588924	9601035	**8678622**	100

Source Countrystat.org

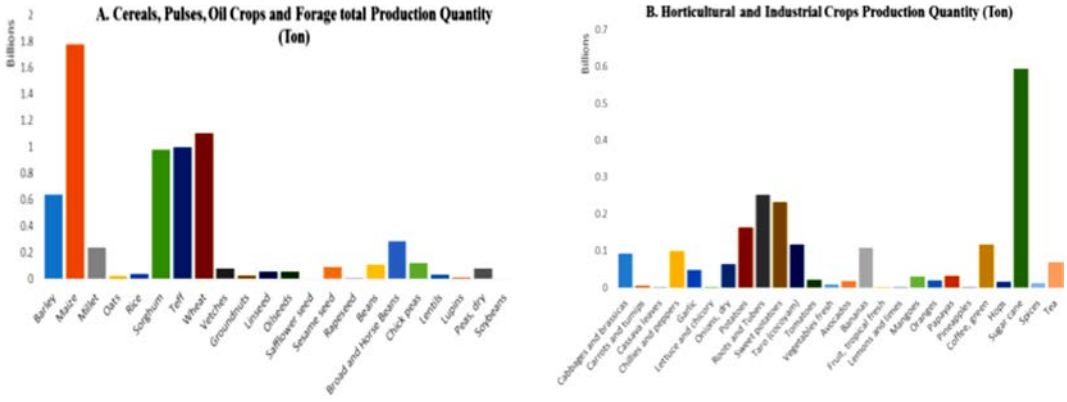


Fig. 7. 10 years average (from 2003 to 2012) Harvest (ton) A) Cereals, Pulses, Oil Crops, and Forage, B) Horticultural and Industrial crops. Source Countrystat.org

the traditional oxen drawn land cultivation. Donkey, horse and camel are also used to transport farm produces to local and distant markets. Official exports of live animals (sheep and goats) are mainly to Egypt, the Sudans and the Middle East, especially Saudi Arabia. There are unrecorded cross-border exports to Djibouti, Somalia, Sudan and Kenya. Domestic demand for meat is huge and it results in local prices increase for cattle, a major bottleneck to exports. Skin and hides are also known contributors to local industries and export (Alemayehu 2006).

Vegetation

Ethiopia's vegetation cover is believed to be less than 10% due to the widespread deforestation, particularly in the highlands, that started at the end of the

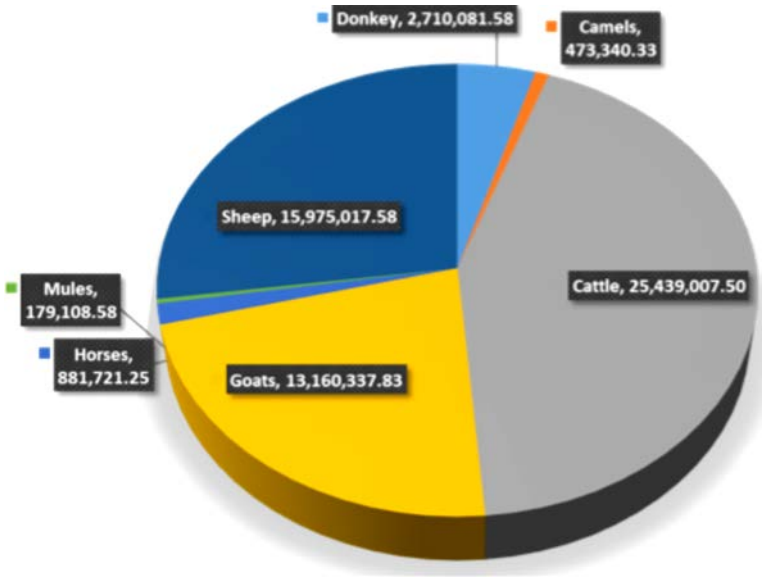


Fig. 8. Major Livestock population of Ethiopia (Countrystat.org).

nineteenth century with the expansion of agriculture. The deforestation rate is estimated to be 200,000 ha/year with most of the surviving forest in remnant patches in inaccessible and remote areas (Alemayehu, 2006).

Irrigation

The irrigation potential of the country is said to be 3.8 million ha (Table 1). However, the area under irrigation is estimated to be under 10% of the total irrigation potential of Ethiopia (Awulachew *et al*., 2007, Hagos *et al*., 2009, MoARD, 2010). The available data from Countrystat.org showed that the irrigated area in 2012 was around 290,000 ha.

The Ministry of Water Resources has identified 560 potential irrigation sites inside the major river basins. Wherever there is irrigation access, the area is covered mostly by cereals (more than 57% of the irrigated land) followed by horticultural crops (25%) (Hagos et al, 2009). Awash River is the only river that is extensively used for commercial plantations of industrial and horticultural crops in the Rift Valley. From the total irrigated agriculture of about 161,125 hectares, over 43% are found in the Awash River basin.

5. *Farming systems, family farming and its contribution to Ethiopian economy*

Farming systems in Ethiopia

The FAO defined a farming system as a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate (Dixon *et al*., 2001). Based on available natural resources and dominant pattern of farm activities and household livelihoods, 15 broad farming systems have been identified by FAO for the developing regions of the world (Dixon *et al*., 2001). Five of them are found in Ethiopia. These are: i) highland perennial, ii) highland temperate mixed, iii) cereal-root crop mixed, iv) maize mixed and v) pastoral farming system. The first four systems are mixed farming system with a main difference on the type of crop grown as main component in the mixed farming.

Mixed systems are defined as farming systems conducted by households or by enterprises where crop cultivation and livestock rearing together form integrated components of a single farming system. They include the livestock systems of landless smallholders that rely on the crop cultivation of neighbouring farms. The main reasons for mixed farming are: spreading of risks over both crops (primary) and livestock (secondary) production, complementarity between crops and livestock and a flexibility that allows the adjustment of crop/livestock ratios in anticipation of risks, opportunities and needs.

Mixed farming in Ethiopia is sub-divided into small-holder farming (small scale or family farming), cooperative, state, commercial farms and forest based farming systems. Most mixed farming systems take place in the *weyna dega* and *dega* zones (Table 3). The crops most suited to grow in the *weyna dega* and *dega* zones are also the most commonly produced crops in Ethiopia. Most producers in these zones are smallholders occupying less than a hectare of land per household on average. Smallholder production is dominated by the five major cereal crops (see above), accounting for almost three quarters of the total cultivated area and about 68% of total production (Dorosh *et al*., 2013).

The other major farming system in Ethiopia is pastoral. The pastoral farming system is home to half of Ethiopia's. However, the land on which these animals graze is unsuitable for farming in all but a few riverine areas. This system is practiced in the arid and semi-arid zones of Ethiopia. Cattle, sheep, goats and camels are the backbone of this farming system. In addition to livestock production agro-pastoral practices exist under the pastoral system. In the agro-pastoral practice, livestock husbandry together with maize and sorghum cultivation is common. (Dorosh *et al*., 2013). Ethiopia's export of live animals (cattle and small ruminants) as well as hide and skin to the world market mainly comes from this farming system. Live animals are usually exported to Sudan and Middle East countries.

Family farming and its contribution

Family farming is a means of organizing agricultural, forestry, fisheries, pastoral and aquaculture production which is managed and operated by a family and predominantly reliant on family labour, including both women and men (FAO, 2014a).

The small-holder farming is most of the time run by family members of the household. About 11.7 million smallholder households account for approximately 95% of agricultural GDP and 80 to 85% of employment. Nearly 55% of all smallholder farmers operate on one hectare or less. (MoARD, 2010) Land holdings are small and often fragmented into many parcels. Farms of less than a hectare comprise more than 26% of agricultural land; almost 60% is in holdings of less than 2 ha and the rest in holdings between 2-2.5 ha. The contribution of family farming in Ethiopia is very high as it produces more than 94% of the food crops as well as 98% of the coffee. Strikingly, the contribution of private, state and commercial farms is negligible. They produce ~6% of the food crops and 2% of the country's coffee production.

6. *Challenges facing family farmers*

Realizing the importance of agriculture, the government has demonstrated a strong commitment to agriculture and rural development through allocations of more than 10% of the total budget. Moreover, the government engaged in expanding coverage of the national agricultural research system into arid and semi-arid areas; training and deploying development (extension) agents to each peasant association; establishing farmer training centres and strengthening research-extension-farmer linkages to improve technology generation, transfer, utilization and feedback (MoARD, 2010).

However, the sector has several problems, which are manifested in the form of low input use, land degradation and low productivity (Alemu *et al.*, 2009). Low agricultural productivity can be attributed to climate change and recurrent drought, limited access to agricultural inputs, financial services, improved and well adapted crop varieties and animal breeds, improved production technologies, irrigation and agricultural markets and land ownership (MoARD, 2010). Although the current land policy assures some security through users' rights, periodic redistribution of land among farmers has been a strong bottleneck to carry out improvement and/or erosion control measures. As a result the land policy (land redistribution) believed to contribute towards poor land management practices that led to severe land degradation (Alemayehu, 2006).

Drought affects the agricultural sector performance with devastating effects on household food security and poverty levels. Vulnerability to droughts is greatest in the pastoral areas of the lowlands and the densely populated, food-insecure districts of the highlands. Drought-induced famines are further exacerbated by limited coping mechanisms and inadequate contingency planning for drought mitigation and the threat of climate change (MoARD, 2010).

7. *Ethiopian Agrobiodiversity*

Ethiopia is one of the Vavilov centres of origin and diversity for several crops and their wild relatives (see Table 4 for list of species) (Vavilov, 1992, Ram and Yadava, 2007). It is considered as the primary gene centre for teff (*Eragrostis tef*), noug (*Guizotia abyssinica*), coffee (*Coffea arabica*), and Ethiopian mustard (*Brassica carinata*). The country harbors important gene pools of crop wild relatives (CWR) for at least 197 species, including grains, pulses, oil seeds, vegetables, tubers, fruits, spices, stimulants, fibers, dyes and medicinal plants. In addition, several crops that were domesticated outside of Ethiopia exhibit a high secondary diversification in Ethiopia, evidenced in farmer varieties (FV) of wheat, barley, and several pulses. It was hypothesized that about 4% of the world crops originated here. (Hummer and Hancock, 2015).

Ethiopia is also known for fauna diversity. There are numerous categories of terrestrial and aquatic resources such as mammals (277 spp.), birds (861 spp.), rep-

Table 4. List of crops originated and with great diversity in Ethiopia.

Cereals	Teff (*Eragrostis tef*), durum wheat (*Triticum durum*), poulard wheat (*Triticum turgidum*), emmer wheat (*Triticum dicoccum*), barley, (*Hordeum vulgare*), sorghum (*Sorghum bicolor*), finger millet (*Eleusine coracana*), pearl millet (*Pennisetum spicatum*)
Pulses	Lentil (*Lens esculenta*), chickpea (*Cicer arietinum*), pea (*Pisum sativum*), faba bean (*Vicia faba*)
Oil crops	Sesame (*Sesamum indicum*), flax (*Linum usitatissimum*), nug (*Guizotia abyssinica*), safflower (*Carthamus tinctorius*)
Vegetables, root and tuber crops	Ethiopian mustard/kale (*Brassica carinata*), shallot (*Allium sp.*), okra (*Hibiscus esculentus*), anchote *(Coccinia abyssinica*), enset *(Ensete ventricosum*), yams (*Dioscorea* spp.), Oromo Dinich (*Plectranthus edulis*)
Spices	Korarima (*Aframomum corrorima*), long pepper (*Piper longum*), black cumin (*Nigella sativa*); white cumin/bishop's weed (*Carum copticum*), coriander (*Coriandrum sativum*), thyme (*Thymus schimperi*), fenugreek (*Trigonella foenum-graecum*)
Stimulants	Coffee (*Coffea arabica*), chat' (*Catha edulis*)
others	Castor (*Ricinus communis*), myrrh (*Commiphora abyssinica*), gesho (*Rhamnus prinoides*), kosso (*Hagenia abyssinica*)

tiles (78 spp.), amphibians (54 spp.) and fishes (101 spp.) out of which 22, 27, 3, 17, and 4, endemic species are recorded, respectively. Domestic animal species that are known to have originated elsewhere have also developed secondary diversification in Ethiopia. This diversity of biological resources is a clear demonstration of ecosystem diversity and biological wealth existing in the country (IBC, 2005).

The diversity of organisms in an ecosystem provides essential functions and services. In addition to foods, medicine, fuel wood, and construction materials, biological resource especially forests provide wildlife habitat and recreational opportunities, prevent soil erosion and flooding, and help provide clean air and water. Biological resources are also important biotic checks to pests and diseases and serve as defense line against global climate change. The indigenous landraces of various crop plants species, their wild relatives, and the wild and weedy species are all highly prized for their potential value as sources of important traits for crop improvement programs. Among the most important traits that are believed to exist in these landraces are, disease and pest resistance, nutritional quality, resistance to drought and other stresses.

8. *The contribution of my PhD project*

Eragrostis tef (teff), member of the *Poaceae* family (Figure 9), is the major cereal crop originated and widely cultivated in Ethiopia where it provides nutrition for two-thirds of the population. In addition, its straw is used as livestock feed and plastering component for construction purposes. Teff is also an important cash crop for small households. It is rich in essential amino acids and minerals (particularly iron and calcium) and it is gluten free. Teff is cultivated by more than 5 million small-scale farmers annually.

Conventional teff breeding efforts started in the late 1950s and since then a total of 24 varieties have been developed and released. However, there are many constraints that still affect teff production and need to be addressed to improve total yield. Lodging is the most important yield limiting factor, accounting for a 25% of yield loss each year.

Since it is originated in Ethiopia, huge genotypic and phenotypic variation exist and more than 4,000 accessions are found in the Genebank of the Ethiopian Biodiversity Institute (EBI). For effective utilization and conservation of germplasm, understanding the crop at molecular level is important.

My PhD research project aims at better characterizing the teff genome using NGS approaches such as RNA and DNA sequencing. RNA-sequencing helps us to understand the expressed fraction of the teff genome, whereas the low coverage DNA sequencing allows us to better characterize the repetitive component of teff genome. We have identified that 27% of the teff genome is composed of repetitive sequences, particularly transposable elements. Moreover, we also identified SSR markers from both NGS data. SSR markers are a set of short repeated DNA

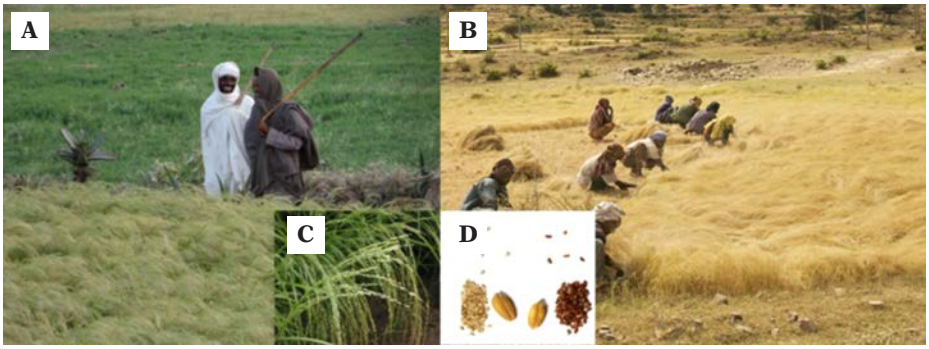


Fig. 9. Teff farm: A) during grain filling; B) harvesting; C) teff panicle and D) grain size comparison against wheat (D).

sequences at a particular locus on a chromosome that vary in number in different individuals and can be used for genetic fingerprinting. Research outputs from this project will be used for teff marker-assisted breeding. We believe that the results of our genomic characterization will contribute to speed up the development of improved teff varieties. Obviously, an additional very important outcome of my research activities in the PhD project is capacity building in the field of genomics and bioinformatics. The program will enabled me to acquire both knowledge and skills in planning and implementing researches at molecular level and make use of different bioinformatics tools in order to analyze molecular data coming for DNA and RNA sequencing. It will be a huge input to Ethiopia's endeavor in molecular and biotechnological research projects.

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