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Coping with catastrophe: Crop diversity and crop production in Tigray National Regional State in Northern Ethiopia

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Tigray, the most northern of Ethiopia's ethnically based regional states, covers an area of 53 386 km^2 and has a population exceeding 5.17 million of whom some 24.3% are urban dwellers. Wide agroclimatic variations result from altitudinal differences (600 to 3000 m) and rainfall patterns. The area is a center of origin of many cultivated and wild plants. The mainly agricultural rural population, farming small areas of non-contiguous plots, makes wide use of these conditions to ensure its livelihood. Crops grown include ten species of cereals, seven pulses (legumes), six oilseeds, and numerous fruits, vegetables and spices. Within these groups and species several varieties or landraces are recognized and used to advantage. Wild species are exploited for food, especially at times of crop failure, and for medicines. Crop production is beset by many biotic (weeds, pests, diseases), abiotic (infertile soils) and anthropic (government policy, civil strife, military actions) constraints. Drought is a frequent occurrence and leads to crop failure and famine. In normal times crop yields are low but some of the production is marketed to provide cash for other necessities. Tigray's population is poverty stricken and often in need of food aid.

Key words: Genetic resources, biodiversity, poverty, drought, food security, famine foods.

INTRODUCTION

Tigray National Regional State is the most northern first-order administrative entity of the Federal Democratic Republic of Ethiopia. The state has an area of 53 386 km^2. In 2016 the human population exceeded 5.17 million of which about 24.3% lived in urban areas (CSA, 2018). Urbanization is proceeding apace as illustrated by the state capital, Mekelle, whose population expanded from about 5000 inhabitants in 1935, to 45000 in 1975, when the current study started, and then to 310000 in 2016 and an estimated 543000 in 2021 (Figure 1) (UN, 2018). More than 97% of the population is ethnic Tigrean. Almost 50% of the population is aged 15 or under.

A traditional ecological classification of the country was brought to the attention of the Western intelligentsia towards the end of the Eighteenth Century (Bruce, 1790) and formalized about 100 years later (Dove, 1890). The

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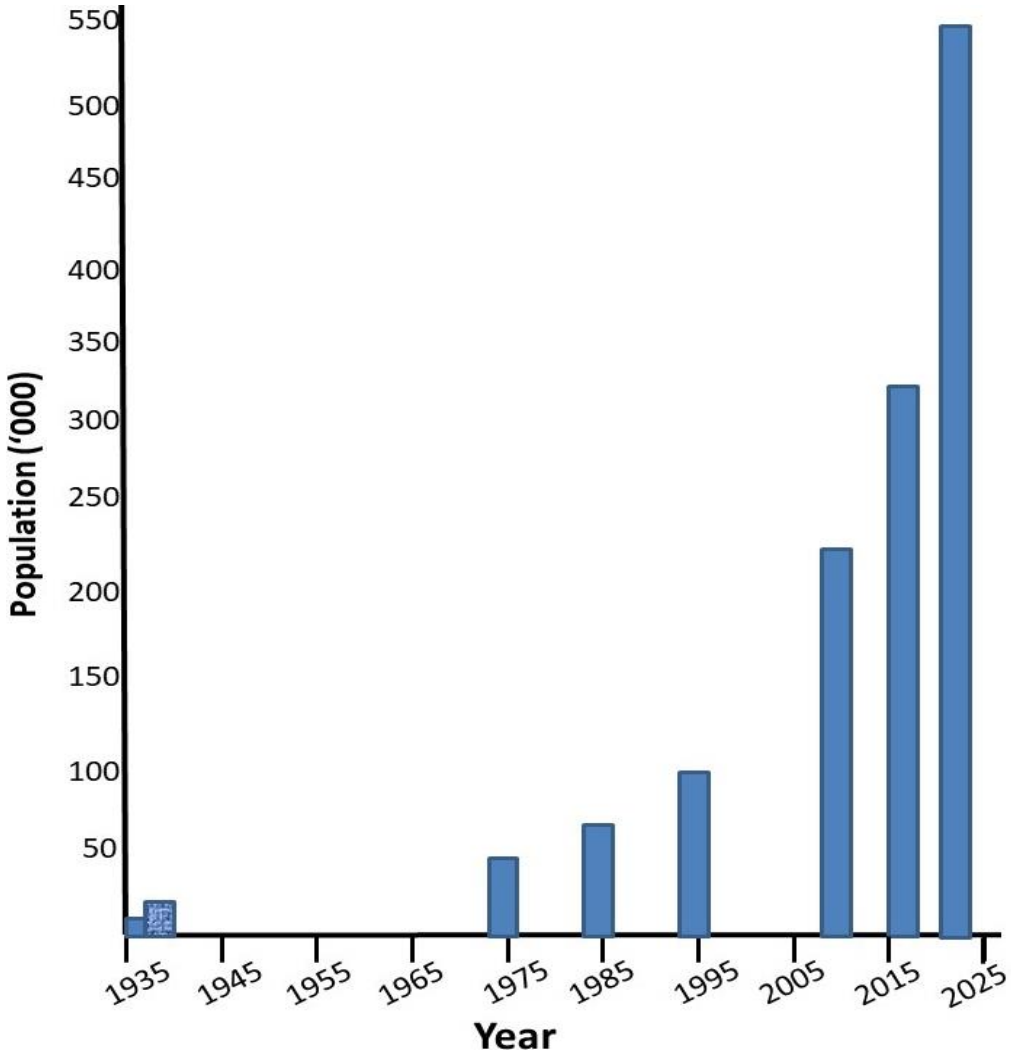

Figure 1. Human population growth of Mekelle, capital city of Tigray, 1935-2021.
Source: Compiled from original data by the author.

main recognized zones are: *kolla* comprising the hot lowlands below 1500 m above sea level with average annual temperatures in excess of 20°C; the *woyna dega* at 1500 to 2500 m with temperatures of 16 to 20°C; and the *dega* or mountainous areas extending up to 3800 m with temperatures below 16°C (Huffnagel, 1961). It is to be noted that this traditional classification is temperature-based and takes no account of rainfall which historically has been rather low and in recent years has been subject to recurring droughts (Gebrehiwot and Fekedu, 2012).

Such rain that falls is irregular in both time and space. Consequent on thousands of years of cultivation soils are degraded, infertile and highly susceptible to erosion. Various anti-erosion methods have been implemented in recent years leading to some success in slowing run-off and soil loss (Munro et al., 2019). Cultivable land remains, nonetheless, at a premium and the steepest slopes continue to be sown to crops by use of terracing that is maintained by hand labor (Figure 2). Over multiple generations the land has become fragmented. Individual holdings are small and usually comprise several small non-contiguous parcels. Crop yields are low with average household production providing food for only 4.5 months of the year (CSA, 2018). Some 1.08 million ha (about 20% of the land area) is considered suitable for agriculture of which about 1.00 million ha (almost 93% of potential arable land) is regularly cultivated. About 300000 ha is suitable for irrigation (WFP, 2009) but not exploited. The huge domestic animal population greatly exceeds the carrying capacity based on the small amount and poor quality of feed resources. Cattle mostly comprise oxen used for plowing and for transport, but these are productively employed for very few days in the year (Wilson, 2003). Continuing degradation of the vegetation is a major problem, much of the original plant cover has disappeared, and remnants remain only in

Figure 2. Cultivation on steep slopes at 3000 m near Maychew; 18 June 1974 and 44 years later on 3 November 2018. Source: Both photos by the author.

church compounds (Wilson, 1977).

Much of the small crop output is lost to pathogens and pests, or by contamination at planting, during growth, at harvesting, and during storage. Weeds are a universal problem. Rodents consume or destroy up to 20% of the cereal crop in non-outbreak years (Afework and Leirs, 1997). It was already observed in the eighteenth century that “the deficiency of the crop is not from the barrenness of the soils but from the immense quantity of field rats and mice that overrun the whole country and hide in the fissures of the earth” (Bruce, 1790). Crops are regularly attacked by passerine birds, notably the red-billed quelea *Quelia quelia*. In addition to mammals and birds, insects are major pests. The desert locust *Schistocerca gregaria* and caterpillars of the moth genus *Spodoptera,* known as army worms, are sporadic in habit but in swarming stages devastate all kinds of vegetation but many insects are crop-specific or limited to a crop group. Shoot flies, stalk borers, midges, crickets and aphids are major pests of cereals (Bijlmakers, 1989). Bollworms cause severe losses in cotton. Fungi are a problem on all types of crops and include rusts, smuts, blights, and mildews.

Crops are not only confronted by biological challenges, but also by physical and anthropic ones which, singly and in combination, contribute to catastrophic consequences. Almost 250 years ago, Bruce (1790) wrote “to these plagues may be added still one, the greatest of them all, bad government, which speedily destroys all the advantages they reap from nature, climate and situation”. Government, vis-à-vis Tigray, continues to be bad in August 2021, with numerous media reports that federal troops are preventing farmers from plowing and sowing and destroying crops *in situ*. The Ethiopian Tewadeho Orthodox Church undoubtedly contributes to poverty and food insecurity, insisting on fasting in order that the faithful shall obtain forgiveness for sins. Fasting, on an average of 180 days a year, is required by all the faithful and includes every Wednesday and Friday. During fasting, all animal products are forbidden and no food or drink is allowed before noon. No heavy labor (including plowing, harvesting and threshing) is allowed. Lost days of work and near-starvation induced weakness clearly have negative effects on food production.

The specter of drought is never far away. There was severe drought in 1973, since then the country has been depicted as a food deficit country whose people and animals suffer from almost constant drought and famine. Droughts of 12 months duration were recorded in 1983 to 1985, 1990 to 1991, 1997 to 1998, 2002 to 2005, and 2009 to 2013 (Amare et al., 2019). In January 2002, the over 5 million food insecure people had become around 14 million by the end of the year. Drought has another insidious effect, animals die or is sold to raise cash to buy staple foods. The loss of livestock, and particularly draft oxen, results in the enlistment for work of other livestock species unused to and inefficient in the provision of energy for cultivation (Figure 3).

Cereal and pulse production in 1984/1985 was only 33% of previous years and only 61% in 1985/1986. Poor performance was related to drought, a policy of controlling prices and of denying free movement of agricultural products from surplus to deficit areas, the unstable political climate, dislocation of the rural community by resettlement, villagization, and conscription to meet military obligations, land tenure problems, further land fragmentation, failure to distribute farm equipment, and fertilizers, and limited access to extension advice (Matouš et al., 2013). In response to malnutrition and famine people migrate from rural to urban areas: during the 1983 to 1985 famine, Mekelle had seven "hunger camps" with 75 000 refugees and a further 20 000 people awaiting admittance. In February 2016 approximately 10.22 million people in Ethiopia were listed as “food insecure” (FAO, 2016).

The cumulative results of the foregoing biological and non-biological constraints are a pervading poverty and an

Figure 3. Abnormal use of animals for land preparation near highland Mekelle after drought-related livestock deaths (Ox in left hand picture is from Ethiopian lowlands and not highlands and note in right hand picture horse and mule having to be led).
Source: Both photos by the author taken in 1975.

almost constant state of malnutrition and starvation. Tigrayan farmers attempt to mitigate these problems through their indigenous knowledge and maximum use of the plant genetic resources available to them.

MATERIALS AND METHODS

This paper is based on empirical observations, detailed field studies, interviews and discussions with farmers (many of them women), market buyers and sellers (many of them women). During this exercise, meetings with administrators, crop scientists, extension workers, key informants and with colleagues on a development study contributed to an understanding of the production problems and possibilities of the Tigray agricultural environment. An in-depth review of the literature was also undertaken.

THE TIGRAY AGRICULTURAL ENVIRONMENT

From a practical perspective Tigray can be best divided into two major agroecological zones. One is a lowland plain at 1500 to 2000 m altitude in the east which is largely in a rain shadow. The other is an upland plateau and hilly area to the west at 1500 to 3000 meters in altitude. The total rainfall amount is misleading, because it obscures the fact that there are two distinct rainy seasons (CSA, 2021) in Tigray, one or other of which, or both, regularly fail. In the *meher* or main rainy period precipitation falls in June to August and crops are harvested from September to February. Lower rainfall occurs in the *belg* season of March to May with crops harvested from March to August. Frosts occur at higher altitudes in December through February. Precipitation may occur as hail at any time of year.

In the lowlands, potential evapo-transpiration exceeds rainfall in most years and renders the area marginal for rainfed cropping. In spite of this, there is extensive dry land cropping. The main crops are sorghum (mainly *Sorghum bicolor* although other “sorghums” are grown), tef, and barley. Wheat, maize, linseed, and pulses are minor crops in the lowlands. Sorghum, tef and maize are usually sown in the short rains in April. Tef is harvested in late June whereas sorghum and maize are slower maturing, completing ripening on residual soil moisture and are generally harvested in September or October. Short season barley and wheat is sown during the main rains of July and a second crop of tef may be grown. Chickpeas are sown in late August and mature on soil moisture.

Rainfall is more reliable and more regular in the highlands and is generally in the range of 500 to 1000 mm per annum. This and lower temperatures allow a wider range of crops. Tef and wheat are co-equal main crops. Barley is of considerable importance. Various “millets” (*Panicum*, *Eleusine*, *Digitaria*, *Setaria* species) are grown as is a range of pulses. Linseed is the main oil crop although neug is preferred on black cotton soils. The cropping pattern is not, however, uniform over the highlands and tends to vary with rainfall which is somewhat higher and more regular in the southwest and diminishes and becomes more irregular to the northeast. Thus, some sorghum and maize is grown in the southeast but barley, wheat, tef and finger millet dominate the north. Similarly, linseed is more common in the south whereas neug is more common in the north.

CROP DIVERSITY AND PRODUCTION

Overview

In 1920, Vavilov postulated that the region of greatest diversity of a plant species is its center of origin (Vavilov, 1935, 1951). Ethiopia is the center of origin of at least 38 plants. Tigrayan farmers maximize this natural capital, cultivating at least ten species (one not indigenous) of cereals, seven pulses, six oilseeds, and numerous fruits and vegetables and spices (Table 1). Several crops can be classified under two or more main groups where different parts of the plant have different uses.

Farmers plant different crops to ensure there will be something to harvest and help to stabilize production, to reduce the risk of total crop failure, to mitigate insect and disease damage, and to use labor more efficiently. If all household needs are fulfilled (and even if they are not) there will be some sales at local markets.

Cereals

Estimates of the number of households growing cereals in 2019/2020 were 1.24 million, the area cultivated being 779519 ha at 0.63 ha per household and a total production of 1 860528 tonnes, equivalent to 2.39 tonnes/ha (Table 2). Cereals (Figure 4) are by far the major crop grown for food and occupy as much as

Table 1. Partial catalogue of food groups and foods within groups made use of in Tigrayan agriculture.

English name	Latin binomial	Tigrinya name	Amharic name	Crop use and notes
Cereals				
Tef (white)	Eragrostis tef	Tenda Teff	Ketch Teff	Preferred cereal for 'njera'
Tef (red)	Eragrostis tef	Kayih Teff	Kay Teff	Preferred cereal for 'njera'
Wheat (hard)	Triticum durum	Sengye	Sindie	Flour for 'ambasha' and pasta
Wheat (soft)	T. aestivum (T. vulgare)		Kollo	Flour for bread; roast grain ('kollo') as snack
Wheat (emmer)	T. dicoccum abyssinicum	Ares	Aja	Local porridge 'g'at'; traditional bread 'kita'; 'kollo'; food for lactating mothers and babies
Barley	Hordeum sativum	Segem	Gebs	Malted for local beer 'tella'; 'g'at'
Finger millet	Eleusine coracana	Dagusha	Dagusa	'tella'; flour mixed with wheat flour for 'ambasha'
Sorghum (white)	Sorghum bicolor	Mashilla	Mashilla	'tella'; mixed with tef for 'njera'
Sorghum (red)		Lequa	Zengada	'tella'; mixed with tef for 'njera'
Maize (yellow)	Zea mays	Mashilla Bahri	Bokollo	flour mixed with wheat flour for baking 'hanza'; cobs and seeds roasted and boiled
Pulses				
Bean (field, horse)	Vicia faba var. abyssinica	Alkuay; Atabahri	Bakella	Split beans in 'kiki wot'; paste for 'shira (= fasting) wot'; roasted
Field pea	Pisum sativum	Ini Ater	Ater	Flour in 'shira wot'
Chickpea	Cicer arietinum	Ater	Chimbra	Pounded to flour; whole grain in 'wot'; roasted
Grass pea	Lathyrus sativus	Asebere; Sebere	Enguaya	Ground with pepper for 'shira wot'
Lentil	Lens esculenta	Burshin	Mesir	Split grain in 'wot'
Fenugreek	Trigonella foenum-graecum	Abaeke	Abish	Medicine, soft drink, 'wot'; also used as a spice
Bean (haricot)	Phaseolus vulgaris	Adengura	Adenguare	Little local use; export market
Oilseeds				
Sesame	Sesamum indicum	Selit	Selete	Oil for cooking; soft drink; flavouring 'wot'; mainly marketed for export
Neug; niger seed	Guizotia abyssinica	Neug	Neug	Oil extraction; cake as livestock feed
Linseed	Linum usitatissimum	Ent'ate	Telba	Oil; pounded and mixed with water as drink; pounded and mixed in 'wot'; flax
Castor	Ricinus communis	Guli	Gulo	Oil used to lubricate cooking plate for 'njera'
Mustard	Brassica carinata	Hamli (Leaf); Hadri (Grain)	Gomen-Zur	Leaf vegetable; oil for cooking; preparation of 'njera'
Safflower	Carthamus tinctorius	Shuf	Suf	Oil for cooking; whole grain roasted
Spices				
Pepper (red)	Capsicum sp.	Berbere	Berbere	Whole dark red/black pod ground to powder with other spices; flavouring for 'wot'
Pepper (black)	Piper nigrum	Selim Berbere	Tikur Berbere	Whole pod ground to powder; flavouring for 'wot'; spice in tea
Clove	Syzygium aromaticum	Kinfer	Kinfer	Ground flower buds added to tea
Ginger	Zingiber officinale	Dendabile	Zingible	Pounded dried rhizomes for flavouring 'wot'
Coriander	Coriandrum sativum	Tsagha	Dembilal	Seed pounded and mixed with peppers for 'dura wot'
Cumin	Cuminum cyminum	Commun	Camon; Azimudi	Pounded seed for flavouring 'wot'
Black cumin	Nigella sativa	Azmud	Tikur Azmud	Ground seed mixed with other peppers and added to 'wot'

Table 1. Contd.

Ethiopian caraway	Trachyspermum ammi	Azmud	Netch Azmud	Ground seed mixed with other peppers and added to 'wot'
Turmeric	Curcuma longa	irdi	ird	Powdered root added to 'wot' for yellow colouring
Rue	Ruta chalepensis	chena adam	tena adam	Pounded capsule mixed with vetch and added to 'wot'; also medicinal plant for stomach ache
Neug	Guizotia abyssinica	awesda	tikur azmud	Ground seed mixed with peppers and added to 'wot;
Ethiopian mustard	Brassica carinata	senafetch	senafetch	Ground seed with peppers and used as sauce for 'njera'
Long pepper	Piper longum	tinzez	timiz	Ground fruit mixed with peppers and added to 'wot'
African cardamom	Aframomum corrorima	korerima	korerima	Ground nut mixed with peppers and added to 'wot'; flavouring for coffee; Ethiopian endemic
Basil	Ocimum ?gratissimum	seseg	basobila	Fruit husks ground with vetch and added to 'shura wot'
Fruits and vegetables				
Prickly pear	Opuntia ficus-indica	beles, gelhi	beles	Fresh fruit
Guava	Psidium sp.	zeitun	zeitun	Fresh fruit
Bekuro lemon	Citrus sp.	bekuro lomin	bekuro lemon	Fresh fruit
Banana	Musa sp.	muz	muz	Fresh fruit
Mandarin	Citrus nobilis	manderini	manderini	Fresh fruit
Peach	Prunus persica	kuk	kuk	Fresh fruit
Onion	Allium spp.	shinkurti	shinkurt	Boiled and added to 'wot'
Garlic	Allium sp.	tsads shinkurti	nech shinkurt	Boiled and added to 'wot'
Tomato	Lycopersicon esculentum	pomidoro	timatim	Fresh vegetable; added to 'wot
"Irish" potato	Solanum tuberosum	dinish	denich	Cooked and sliced for 'wot'
Spinach beet	Beta cicla	kosta	kosta	Boiled leaf, shredded and added to 'wot'
Cabbage	Brassica sp.	tiklul-hamli	tiklegomen	Boiled leaf, shredded and added to 'wot'
Mustard	Brassica sp.	hamli		Boiled leaf, shredded and added to 'wot'
Miscellaneous				
Cotton	Gossypium sp.	tut	tut	Local spinning and weaving as cottage industry
Coffee	Coffea arabica	bun	bunna	Beans roasted and pounded for drink
Buckthorn	Rhamnus prinoides	gesho	gesho	Pounded dried leaves and malted barley for 'tella'; mixed with honey to ferment 'tej'
("Busy Lizzie")	Impatiens tinctoria	sasila	insosila	Ground roots used as colouring cosmetic
Christthorn	Ziziphus spina-christi	gaba		Raw berry eaten as fruit
Soapberry	Phytolacca dodecandra	shebti	endod	Pounded fruit capsule used as washing soap
African redwood	Hagenia abyssinica	habi	kosso	Therapeutic for tapeworm infestation
Embelia	Embelia schimperi	enkoko	enkoko	Therapeutic for tapeworm infestation
("Dock")	Rumex abyssinicus	mekmoko		Red dye from roots used fas a cosmetic: decoction of roots for a drink
		kuni		Ground woody rhizomes used to perfume hair

Phonetic spelling of Tigrinya and Amharic words is not definitive!.
Source: Original Table from Vogt (1975) greatly expanded by the present Author.

Table 2. Basic data for Tigray Region on number of households, area planted and yields of principal cereal, pulse and oil seed crops in meher season 2019/2020.

Crop	Households cultivating (no)	Area planted (ha)	Area per household (ha)	Yield per ha (tonnes)
Cereals				
Tef	633 525	188 392	0.297	1.655
Wheat[a]	386 778	102 258	0.264	2.190
Barley	419 786	85 431	0.203	1.881
Finger millet	369 685	90 199	0.243	2.392
Sorghum	558 917	232 636	0.416	3.013
Maize	835 782	80 151	0.095	3.075
Pulses				
Field beans	214 391	11 868	0.055	1.661
Field peas	94 466	7 741	0.082	1.459
Chickpea	35 361	7 566	0.214	1.561
Grass pea	39 081	7 174	0.184	1.705
Lentil	59 064	6 930	0.117	1.115
Fenugreek	13 199	603	0.046	?
Haricot bean[b]	33 903	3 516	0.104	1.661
Oilseeds				
Sesame	145 151	108 291	0.746	0.749
Neug	30 675	5 598	0.182	1.510
Linseed	48 592	4 138	0.085	1.033

a- Three species combined. b- White variety only; red variety 1968 farmers growing but no other data.
Source: Adapted from CSA (2021).

Figure 4. Cereal biodiversity in Tigray (A - Crop and ears of tef; B - Crop and ears of Emmer wheat; C - Crop and ears of barley (this variety for local beer); D - Finger millet crop and ears; E - Panicles of two of the three varieties of sorghum commonly grown).
Source: All photographs by the author.

90% of the cultivated area and are grown by more than 90% of farm households in both the highlands and lowlands. Cereals account for more than 60% of rural employment and provide more than 60% of total caloric intake. They mainly provide staple foods but some species are used in brewing alcoholic beverages and preparing specialty ethnic foods (Nigussie et al., 2020). Approximately 45% of production is consumed by the household, the remainder being saved for replanting, sold, fed to livestock or used to pay hired labor. Oats, *Avena* species, are not a crop in Tigray but are a common weed, especially in wheat, at 2200 to 2800 m altitude (Ladizinsky, 1975).

Tef

Tef, both white and red varieties, is the iconic and preferred Tigrayan cereal for making the traditional unleavened bread *njera* (*njera* is Amharic, the Tigrinya name being *taita* although the Amharic designation is commonly used throughout Tigray). Tef has an extremely small gluten free grain. It is used mainly by the household thus it is expensive and sometimes elusive in markets. The flour is often mixed with other cereal flours that may also be used alone. The spongy bread, smooth below and bubbly above is made from a slightly fermented batter baked on a large round surface, is the basis of many meals. Tef is a preferred crop in other ways as it can be sown later than other cereals and different varieties are grown at different altitudes. The straw is fed to livestock or used as binding in the mud plaster of house walls. Mineral fertilizer and insecticides are occasionally applied. A Bush Cricket and the Black Tef Beetle are major insect pests.

Wheat

The area cultivated to wheat in Tigray in 2019/2020 was the third largest cereal crop after sorghum and tef. The three species grown in Tigray are planted over approximately the same area as tef. Durum wheat *Triticum durum* is the most widespread and its genetic and morphologic diversities are widely exploited (Lijalem et al., 2021) although the traditional *shahan* variety is often preferred. The flour is mainly made into *ambasha* or *dabo* which is a round, somewhat flattened, leavened bread, but, in part as a relic of the Italian occupation of the 1930s, there is some small scale commercial production of pasta.

Common wheat *Triticum aestivum* is the most widely grown cereal in the world. It has never been quite so common as *durum* in Ethiopia, but consequent on varietal improvement and extension pressure it has become more popular throughout most of the country. A variety released in 2011 by the Mekelle Agricultural Research Centre, suitable to rainfall of 300 to 500 mm at altitudes of 2000 to 2500 m and maturing in 90 to 95 days was a semi-dwarf type with good resistance to water stress (Hintsa et al., 2011): in 2018, discussions with farmers showed that they were largely unaware of this cultivar.

Emmer wheat *Triticum turgidum*, sometimes known as hulled wheat, is an awned relict type in most areas but is still popular in Tigray. Emmer, introduced to Ethiopia about 5000 years ago, has cultural and sociological importance, and occupies 7 to 10% of the total area of the wheat crop (D'Andrea and Mitiku, 2002). Because the grain is hulled, threshing is a heavy and labor-intensive process invariably undertaken by women, but this is considered worthwhile due to the taste and texture of the grain's processed products. This traditional plant is lauded as being good for lactating mothers and farmers believe that it helps to set broken bones (Bethlehem et al., 2019).

Purple grains, caused by anthocyanins in the pericarp, occur in tetraploid wheats from Ethiopia (whence they were first introduced to Europe in the early twentieth century): anthocyanins have potential health benefits as antioxidants (Zeven, 1991). Stem borers, shoot flies and aphids are important insect pests (Abebaw, 2018). Rusts are a major fungal problem of wheat in Tigray (Tesfay et al., 2016). Local wheat varieties vary in their susceptibility to rust but as the fungus is so labile new varieties very quickly become infected. A recent study found ergot *Claviceps purpurea*, which has caused outbreaks of human ergotism over the years, to be present in Ethiopia only on wild oats *Avena abyssinica* at altitudes of 2300 to 3000 m (Dawit, 2017). Ergot is known to infect other cereals including wheat and barley: the author of this paper identified typical sclerotia of ergot on a wheat crop near Mekelle in 1974. As a major staple crop, wheat benefits more than most other crops from mineral fertilization and insecticide application, and occasionally from the use of fungicides.

Barley

Barley was fifth in the area of cereals cultivated in Tigray in 2019/2020. Ethiopian barley is mainly a 2-row type, which is preferred for its low protein and better malting qualities and may account for it not receiving much fertilizer. Cultivation over millennia has resulted in development of many ecotypes including *burguda* and *saessea* (D'Andrea and Mitiku, 2002). At least 15 landraces are recognized by farmers on the basis of quantitative and qualitative traits (Hailemichael and Sopade, 2011). The higher elevations and impoverished soils of Tigray are ideal for barley production. Barley is highly nutritious and is the basic ingredient in many solid and liquid foods. It is important in the socioeconomic and cultural life of Ethiopians (Jemal et al., 2016). Roasted whole grain, raw and roasted milled grain, and cracked grain are used in main, side, ceremonial, and restorative dishes. An important use is providing the substrate for brewing *tella* (*siwa* in Tigrinya but the Amharic appellation is in common use). *Tella* is the commonest of several traditional alcoholic drinks, it is mildly acidic in taste and contains 2 to 6%, and occasionally up to 7% alcohol (Mooha et al., 2015).

Barley shoot flies and aphids are the main insect pests. Fungal infections include scald, net blotch, rusts, smuts, mildews, wilts, and blights. Barley yellow dwarf virus (BYDB), transmitted by aphids is widespread in all cereal crops and can reduce yields by as much as 50% (Jansen, 1981). Fertilizers and crop protection products are rarely applied to barley in Tigray.

Finger millet

Finger millet occupied fourth position in area among cereals cultivated in Tigray in 2019/2020. Its adaptability in a wide range of environments with minimal input, a short growing season, tolerance of acid soils, tolerance of drought, and overall production on marginal land where other crops fail, meaning it is a critical all-round crop for food security and human welfare. The high calcium content makes it important as a food for children, and for pregnant and lactating women (Hailu et al., 2021). Local farmers carry out pre- and post-harvest selection and have knowledge of at least 37 landraces or varieties (Yemane et al., 2006).

Sorghum

Sorghum is the most widespread cereal in Tigray, grown mostly in the lowlands and the southwest highlands. Sorghum is the principal food crop in the lowland area of eastern Tigray and in the neighboring Afar Region, not only of farmers but also of families that are mainly livestock owners rather than cultivators. Ethiopia is a center of origin for sorghum (Firew, 2008). At least 60 landraces are recognized, in part based on farmers' knowledge of performance

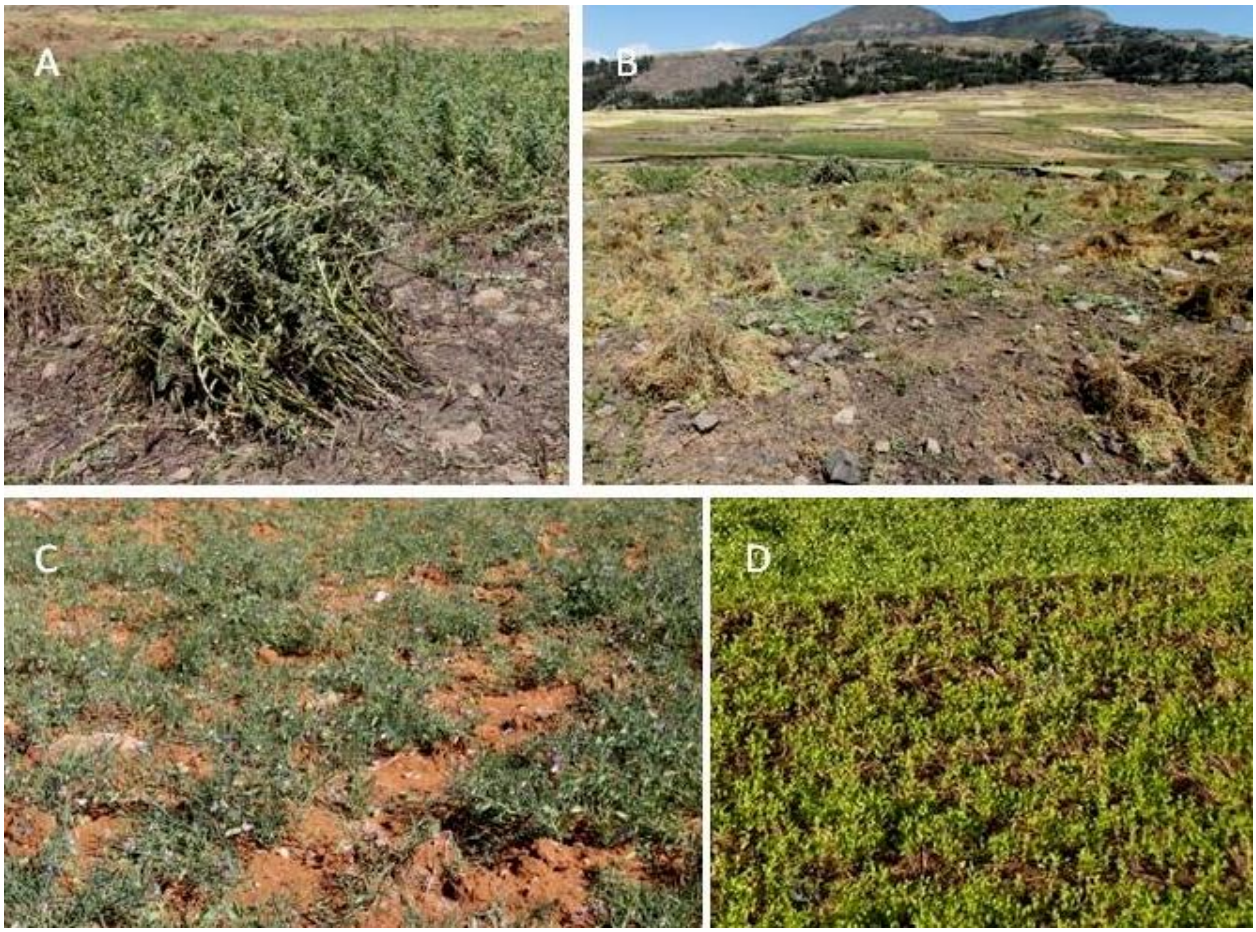

Figure 5. Pulse biodiversity in Tigray (A - Harvested and standing crop of field beans; B - Harvested lentils; C - Growing grass pea; D - Growing chickpea).
Source: All photographs by the author.

during storage (Awegechew et al., 1997, 1999). Farmers also grow several varieties at the same time to reduce risk, and hasten maturity in time for, short season varieties (60 to 75 days) being preferred if there is a perception of a poor rainy season and long season ones (90 to 120 days) if conditions are considered to be better (Nega and Sanders, 2006). It is used to make bread as well as its main culinary use as a stiff porridge. Haulms are fed to livestock and provide structural and roofing materials for houses and fences.

A major production constraint is the obligate root parasitic witch weed, *Striga hermonthica*, which can reduce yields by up to 70% or even destroy the plant altogether. Sorghum, however, is prey to a broad range of insect and fungal pests. Insects include stalk borer, shootfly, midge, and rice weevil during storage. Among fungi are anthracnose, grain mold, gray leaf spot, rust, smut, ergot (*Claviceps sorghi*, also known as *Sphacelia sorghi*), downy mildew, and leaf blight.

Maize

Maize occupied the smallest area of Tigray's cereal crops in 2019/2020. Maize arrived in Ethiopia in the late seventeenth century and was mainly grown as a subsistence crop in the mid-altitudes (1500-2000 m) in the south of the country (Huffnagel, 1961). The production system up to the 1970s was truly subsistence, yields barely exceeding 1 tonne/ha. Maize in Tigray is produced mainly in the northwest lowlands and in the center of the region where climate and soils are more suited to it. Maize was a little-known crop in Tigray before the drought and famine of 1984 to 1985 but became popularized through free distribution of seeds and as a by product of famine relief operations. Early nondescript varieties have recently been largely replaced by higher producing ones.

Much of the crop is sold green on the cob in local markets or as slightly more mature cobs which are eaten roasted. Mature seed is also sold or roasted at home and converted into porridge. The haulm, as for sorghum, is used as animal feed and as a building material.

Maize output is reduced by a plethora of pests and diseases. Stalk borers, termites, weevils and the large grain borer are common insect pests. Leaf blight, gray leaf spot, and common leaf rust are fungal pathogens. Enormous damage is caused by Maize Streak Virus (MSV) and Maize Lethal Necrosis Disease (MLND).

Pulses

Pulse crops (Figure 5), grown more extensively in Tigray than in most other parts of the country are cultivated from sea level to 3000

m. The total pulse area in 2019/2020 at 46577 ha was, nonetheless, only 5.9% of the area of cereals. Pulses were grown by 405006 household, on an average area of 0.12 ha, producing a total yield of 70216 tonnes equivalent to 1.51 tonnes/ha (CSA, 2021). Pulses are eaten boiled or roasted or as an ingredient in a stewed dish known as *wot*, that is often a main plate or taken as a secondary food. Pulses are the most important element in the national diet after cereals and are the main protein source for most people. They are especially important on fasting days when meat is forbidden and *misir wot* (lentil), *kik wot* (pea), or *shiro wot* (bean and chickpeas) are substituted for meat stews.

Horse, field or faba beans occupied just over 25% of the area sown to pulses in 2019/2020. Beans are critical to household nutrition as they are high in protein and contribute to a diversified diet. In the field, the crop improves soil fertility through nitrogen fixation and helps to reduce pest and weed infestation. Landrace varieties are, however, extremely susceptible to broomrape, a root parasite that regularly reduces crop yields by up to 80%. Broomrape (*Orobanche crenata*) is widespread in Ethiopia, is continuing to spread very rapidly, and afflicts all pulse species. Conventional control methods are ineffective so the approach is to breed resistant or tolerant varieties and attempt to persuade farmers to exchange these for their own native types (Birhanu and Tsehaye, 2020). Other economically important diseases of beans (and of other pulses) are chocolate spot, bean rust, aschochyta blight, black root rot and various viruses and nematodes (Addis Tegegn et al., 2019).

Field peas were the second most popular pulse grown in 2019/2020, occupying 16.6% of the pulse area. Uses for food and in the farming system are similar to those of field beans. There is great genetic diversity in field peas in Ethiopia which local farmers have made good use of (Gemechu et al., 2005).

A little known subspecies of *Pisum sativum* restricted to the highlands of South Tigray and North Wello (and to Southern Yemen) is *P. s. abyssinicum*, known in Tigrinya as *dekoko* (= minute seeded). It differs from the standard pea in having leaves with serrated edges (Haddis and Dargie, 2013). This subspecies exhibits high genetic diversity related mainly to altitude, it is considered a highly nutritious ingredient of *wot* and soups, and sells for twice as much as common pea in local markets (Berhane and Berhanu, 2016).

Third place in area was chickpea, planted on 16.2% of the pulse area. Ethiopia is a secondary center of genetic diversity for chickpea and its wild relative *Cicer cuneatum*. As for other pulses it is an important fasting food. Mainly consumed by rural households in the past, an urban market has been developed as people become more aware of the health benefits of a varied diet. A major advantage of chickpea is its drought resistance. It is almost always grown on residual soil moisture after other crops have been harvested (Yadeta and Geletu, 2002). It is therefore “free” and does not occupy land on which less drought resistant crops must rely. Farmers widely exploit the characteristics of the hundreds of landraces of this crop. Local types are generally low yielding (although once again they are not in competition with other crops for land and other resources). Research interest concentrates on higher yields and better seed quality with a view to building an export market (which may possibly serve to supplement farmer income).

The grass pea was the fourth most important pulse in terms of area occupying 15.4% in 2019/2020. Northern Ethiopia is probably a primary center of origin for this species. It is resistant to drought, to salinity, and to waterlogging and is tolerant of low soil fertility. A major negative is its content of Oxalyldiaminopropionic acid (ODAP) which, when ingested, can cause neurolathyrism in humans, a motor neuron degenerative disease that results in lower-body paralysis (Dejene and Korbu, 2012). As with other food crops there is considerable variation in the species related mainly to geography and altitude (Wuletaw and Endashaw, 2003). Research efforts to reduce the ODAP content have not been very successful; this does not prevent its use as a food in a manner analogous to other pulses.

Lentils occupied 14.9% of the pulse area in 2019/2020. Lentils are grown as a protein rich (23-24%) nutritious food crop, as a marketable product locally which commands a high price and as an export crop. The seed, mostly splits before further processing, is higher in protein, carbohydrate and calories than other legumes. It is used as main and side dishes, and in salads. Ground seeds are used in soups and *wot* and mixed with cereals in bread and cakes. Lentils are an excellent infant food (Matny, 2015). Grown in rotation with cereals its nitrogen-fixing properties add to soil fertility and help to break cereal disease cycles (Edossa et al., 2007).

Fenugreek is a very minor crop in Tigray, grown in very small plots on only 603 ha, almost all in the south of the state, in 2019/2020, despite the fact that several local cultivars are recognized by Tigrayan farmers. Its use as a food is similar to that of other pulses but the leaves are also used as a green vegetable. Fenugreek is moderately resistant to *Cercospera* leaf spot (Kassa et al., 2020). Fenugreek seeds are a good source of essential metals, but also contain large amounts of toxic cadmium and lead (Mebrahtu and Chandravanshi, 2016).

Haricot beans are not a traditional crop in Tigray. Many people will not eat them in the belief that they cause stomach upsets, and particularly flatulence. In spite of this, there has been some uptake of haricot cultivation due to government pressure to increase exports of pulses (Tadesse, 2019).

Oil seeds

In 2019/2020, oilseeds (Figure 6) were sown in Tigray on 119570 ha, equivalent to 15.3% of the cereal area, grown by 216195 families with an average oilseed area of 0.55 ha. The total output of 96121 tonnes resulted from an area yield of 0.80 tonnes/ha.

Sesame, grown on 108291 ha in 2019/2020, was by far the major oilseed crop in Tigray but yielded only 0.75 tonnes/ha of seed (CSA, 2021). This crop is largely confined to the lowland west and northwest of the state centered on the town of Humera close to the borders with Sudan and Eritrea, at an altitude of 600 to 900 m. Sesame is produced by both smallholder farmers and small scale commercial farmers. Producers sell small quantities locally on the nearest market or through various kinds of associations. Some sesame is milled locally but most seed is exported, sesame is second only to coffee in Ethiopian export revenue. Ethiopian sesame is of renowned quality and commands a premium price in Israel and the United Arab Emirates where it is converted to tahini (Terefe, 2016). Sales of sesame provide much needed cash for poor farmers with which they can buy food and other necessities but it is certain that they do not receive the share of the final price to which they are entitled. More than 80 weed species have been identified as pests of sesame in western Tigray with *Commelina foecunda* being the most troublesome. Blight, powdery mildew, fusarium wilt, and leaf spot are major bacterial and fungal pests and may be transmitted by a leafhopper (Yirga et al., 2018).

Niger seed, *Guizotia abyssinica*, more commonly referred to in Ethiopia by its demotic name of *neug*, is native to Ethiopia. The crop occupies about 40% of all oilseeds nationwide but is grown on less than 5% of the oil seed area in Tigray where its average yield in 2019/2021 was about 1.5 tonnes/ha (CSA, 2021). The seed contains about 40% oil and 20% protein. Niger oil is highly prized on account of its light color and nutty taste. After pressing the residual cake, with up to 30% protein, is a valuable livestock feed that is reserved mainly for work oxen. Yield losses due to various diseases and insect pests can be considerable. Leaf spots, stem and root rots, and mildews are the major pathogens. Insect pests include Lepidopteran larvae, stem borers and aphids. The niger capsule fly *Dioxyna sororcula* is an important pest of neug

Figure 6. Oil seed biodiversity in Tigray (A - Neug (Niger Seed), *Guizotia abyssinica* ripening on black cotton soil; B - Seeds of Castor *Ricinis communis* on sale at a local market; C and D - Linseed *Linum usitatissimum* on shallow soil and seed head of almost ripe plant near Maychew, southern Tigray).
Source: All photographs by the author.

throughout its range (Schmutterer, 1971).

At the national level, linseed is grown on about 10% of the total oil seed area but in Tigray it is less than 4% of that of oil seeds as a whole. Linseed crops yielded just about 1.0 tonne/ha in 2019/2020. Ethiopia is a secondary center of diversity for this crop where at least 203 landraces have been identified (Worku and Heslop-Harrison, 2018). It is possible that Ethiopia's wide agroclimatic range has contributed to diversification in this oil crop (Birhanu et al., 2020). In southern Tigray significant differences were observed among 12 genotypes in plant height, seed size, and days to maturity. The seed is used for oil whereas the stem converts to flax fiber. The oil content, which has drying properties, is in the range of 35 to 44%. Extracted oil is mostly for home use but some is marketed. The seed is roasted, ground and mixed with spices for eating with local bread, is used in soups, is an ingredient of *wot* and soft drinks, and is a constituent in porridges.

Castor, common mustard and safflower are very minor oilseed crops in Tigray. There is virtually no production of soybeans nor of peanuts. Oil extracted from minor crops is used locally for cooking.

Spices

Most of the world's known spices, many imported, are used in Ethiopian culinary practice. Those cultivated in the country are grown in small plots or intercropped with other food plants. In addition to cultivation, some are collected in the wild (Jansen, 1981). Use of these plants, many used in the traditional pharmacopeia (Meaza et al., 2015), and others that could produce essential oils, is not confined to Tigray but is similar throughout Ethiopia (Zuberi et al., 2014). The use and value of spices in Ethiopian cuisine cannot be overestimated as they are a part of most dishes and especially important in *wot*. Spices are also important items in local trade, providing diversified income, especially for women (Figure 7).

The most widely grown and used spice in Ethiopia is the ubiquitous *berbere*, one or more species of *Capsicum*, usually known as chili in English, each of which may comprise several varieties. Mixed with other spices, it is the basic hot ingredient of most *wot* dishes and can be found in every local market (Figure 7). The crop is widely gown in small plots close to the house where it can be protected against theft and fertilized with the manure of the work oxen and other domestic stock. It has been said of chili that "it requires such intensive care, that it dominates the farmer's life, especially at the seedling production stage" (Tewolde and Gebre, 1984). A very pungent variant is known as *mitmita*. Several concoctions are used to cure real or assumed illnesses. Various fungi can cause considerable reduction in yield, including leaf spots *Cercospera* species, powdery mildew and root rot.

Small scale cultivation of coriander, *Coriandrum sativum*, provides a typical example of traditional production. Its planting is widespread and it is almost universal in local markets. Several varieties are distinguished based on life cycle (long or short growing season), disease resistance, yield, color and oil content. Leaves

Figure 7. Miscellaneous crops (A - Local market, southern Tigray; B -*Berbere* seed cases on sale; C - various spices displayed for sale; D - Bark chips of *Juniperus procera* for cooking and aromatic plants for perfuming of houses; E - Root tubers of *Impatiens tinctoria* for processing into a dye).
Source: All photographs by the Author at a local market near Debub, southern Tigray, November 3, 2018.

are used as an aromatic herb in bread, tea and *wot*, whereas the fruits have a wide range of uses including as an indispensable ingredient of *berbere*. As for coriander, cumin (*Cuminum cyminum*) and black cumin (*Nigella sativa*) are widely cultivated and are omnipresent in markets. Ethiopian mustard used for oil has high levels of undesirable glucosinolates and erucic acid (Getinet et al., 1997). The use and presence of other spices are listed in Table 1. Heavy losses of fruit for most spices can be caused by dipterous flies and most plants are susceptible to *Fusarium* wilts, mildews and root rots.

Fruits and vegetables

Official data for 2019/2020 indicate that just over 56 000 households (4.5% of all households) grew fruit crops on 937 ha (0.1% of all cultivated land) in Tigray. In the same year 327700 households (26%), including those growing chili peppers, grew vegetables and root crops on 6060 ha (0.64% of cultivated land) (CSA, 2021). Fruits and vegetables are important sources of vitamins (especially Vitamin C), minerals and fiber and thus contribute health benefits. They also complement other food production in that fruits are perennial crops requiring little input and vegetables are short season crops that do not compete for labor and other inputs with the main cereal, pulse and oilseed crops. These products are grown for home consumption and for local sales. Women and children are the main beneficiaries of the output (physical and monetary) of these minor crops. Food value and income are both negatively affected by poor cultural practices and incorrect handling both in storage and in transport to markets (Hagos et al., 2018).

The fruits of prickly pear *Opuntia ficus-indica*, a species introduced to Eritrea by the Italian administration but now an invasive alien, are eaten by children at all times and generally by adults during famines. They are also a source of income and are sold in many Tigrayan markets. Among the cultivated fruits, guava and lemons are most common both for home consumption and for sales. Other fruits (Table 1) are less commonly grown.

Onions and garlic, universal basic ingredients in *wot*, are the most cultivated and most productive of all vegetables. Tomatoes, widely used in *wot* and other dishes, and Irish potatoes, spinach beet and cabbage are other main vegetables.

Miscellaneous

In addition to food crops, Tigrayan farmers grow cotton and coffee as minor crops. Indigenous knowledge handed down generation after generation for hundreds of years is drawn on in times of need to use the non-cultivated natural resources of the region as famine food, as medicine and as a marketable product. Leaves, twigs, flowers, fruits and roots of many species are used in various ways for these purposes.

Cotton production is confined to the northwestern lowlands which are also the site of Sesame production. Yields are low due to poor agronomic practices and poor quality seed (Zenawi et al., 2020). Raw cotton is the basis of cottage weaving which adds a diversified source of income to poor households: modern commercial cotton weaving enterprises in Mekelle provide employment opportunities for urbanites. Coffee is another very minor crop, grown in the southern and eastern lowlands of the Region. A local landrace is the principal genetic resource. In spite of low yields and poor practice, such as mixing unripe and ripe berries for drying and improper storage, “it is possible to produce high quality Tigray coffee for global market and enable the region to diversify foreign earnings largely to improve the livelihood of rural people in the region” (Abrar and Negussie, 2013).

Buckthorn, *Rhamnus prinoides*, is predominately a wild shrub that grows at altitudes of 1500 to 2500 m, but because of its many qualities and uses, trees may be planted close to the homestead. It flowers and fruits all year round. The leaves and woody parts are used in brewing of *tella* and *tej*, and in the distillation of *araki* from either of these. Buckthorn, like hops in western brewing, imparts a slightly bitter flavor to the drink (Nigussie et al., 2020).

Impatiens tinctoria is commonly harvested from the wild although it is also grown as a cash crop in parts of Tigray (Cronin et al., 2013). It is a popular dye plant that is also used medicinally. Women mash the tuberous roots (Figure 7) into a paste that is left to steep for 12 h. The mash is then heated and the paste applied to the palms and nails of the hands (for young girls) or to the hands and feet (adult women) to dye them in intricate patterns in a dark reddish color. This beauty treatment also helps to control fungal infections and toughen the skin. The product is used to dye cloth and is an ingredient of a red ink (Sileshi et al., 2020).

Christ thorn (or Christ thorn jujube) *Ziziphus spina-christi* is a widespread species across northern Africa. It is truly a multipurpose wild tree and is sometimes considered an invasive alien. Best known for its edible fruits, which are high in Vitamin C and are eaten raw, it is also a useful firewood tree, makes excellent charcoal and has medicinal uses mainly as a cure for dandruff (Fitsumbirhan, 2018).

Sometimes known as the soapberry, the most common use of *Phytolacca dodecandra* is as a soap and a shampoo. The dried and powdered berries are also used to stun fish, to kill snails, and are possibly effective in controlling schistosomiasis (Kebede and Abd El-Aty, 2021). An extract is also effective in controlling chocolate spot on pulses (Addisu et al., 2019). It is widespread in the wild and is preserved in churchyards (Wilson, 1977).

Tapeworm infestation in humans was very common in the past and persists to some extent to the present and results from eating raw beef. Many plants are believed to be curative for this problem. The dried flowers of *Hagenia abyssinica* are, however, the most widely used of all tapeworm expellants (Edilu et al., 2020). The monthly cure is a strong purgative and often causes a strong debilitating reaction. The second most common wild plant treatment for tapeworms is *Embelia schimperi*, whose dried fruits are the main active ingredient (Yared et al., 2015). The use of *Embelia* as a tapeworm cure is not confined to Ethiopia as it is also found in Tanzania and Kenya (Bøgh et al., 1996).

Various parts of *Rumex abyssinicus* are used for a variety of reasons. As for the two previous plants it is considered to be a vermicide and is also a cure for headaches (Fitsumbirhan, 2018). It has been recorded as reducing hypertension (Yirga, 2010), a dried preparation of the root has antibacterial properties (Zelalem and Dula, 2019), and preparations of the root are used in a drink and to prepare a cosmetic dye as for *Impatiens tinctoria*

DISCUSSION

Tigray is home to more than 5.7 million people, about 75% of whom are rural small scale farmers. Much of the area has low and erratic rainfall and soil nutrients have been depleted over many hundreds of years of agricultural exploitation. The varied agroclimatic conditions nonetheless support a rich diversity of wild and cultivated plants (Harlan, 1969). Biodiversity contributes to food, medicine, textile, fiber, fuelwood, and other resources essential to human survival.

Ethiopia (including especially Tigray) is an important center of origin of biodiversity. Farmers are well aware of and make use of these resources by selecting and using the several species and possibly hundreds of landraces in what is, essentially, their struggle for survival. Diversity allows farmers to garner over an extended period within the year, a range of varied and valuable food and non-food products. Loss of diversity reduces food choices and affects food and nutrition security in addition to resilience to change (Elisabetta et al., 2013). Biodiversity has, however, been declining in recent years. This decline is attributed to both natural and anthropogenic pressures. These pressures can be categorized as: (i) environmental (climate change, land use and cover

changes, invasive and alien species; (ii) social (demographic change, urbanization, rural development; (iii) economic (replacement of traditional crops and varieties with higher yielding ones, commercialization, global markets, consumer food preferences, government policy, labor shortages); (iv) cultural (modernization, taboos, loss of traditional knowledge, customary practices; and (v) governance and institutions (poverty, civil strife, military operations).

Tigrayan farmers have proved to be very adaptable and resilient to continually changing contexts. The mining of the limited areas of land suitable for agriculture coupled to a population constantly on the increase do, however, make it more and more difficult to provide enough food for their families and produce a surplus for sale. Urbanization will exacerbate food insecurity and increase poverty as fewer farmers produce less food. Urban immigrants rarely find remunerative employment and “idle hands are the devil’s workshop”, contributing to civil unrest and antagonism between town and country.

Modern research tends to diminish biodiversity as it often ignores indigenous knowledge and strives for higher yields, which may mean more expensive inputs, in a few selected crops. More effort is needed in the areas of research, development, and policy. Political commitment, policy development and enforcement, and a participatory approach are critical for long-term production increases whilst ensuring that the region’s unique natural resources are not diminished. Tigray’s farmers are making the best use they can of these resources but would be helped to improve their welfare and livelihoods

Varietal diversity in crops increases crop production and food security (Elisabetta et al., 2013). Government policy and the extension services should encourage diversity in addition to promoting increased production. Constraints to higher output include irrelevant research, limited availability of improved varieties, lack of a formal seed delivery system, and reluctance of farmers to adopt improved genetics and new technology. Tigray’s farmers struggle to survive but in feeding themselves and contributing to the national food bank they deserve more support than they are given.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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