# 16.

# Agrobiodiversity and coping with variability in weather and soils

## 1. GENERAL INFORMATION

### *1.1 Title of the practice or experience*

Agrobiodiversity and coping with variability in weather and soils. (Elasticity for coping with variability in weather and soil afforded by agrobiodiversity in Ethiopia – **A** study of the cereal-culture complex as an example.)

### *1.2 Category of practice/experience and brief description*

The environment of Ethiopia is very varied. Because of the wide range of diversification within and among crops, choosing the most suited from among them to specified environmental conditions, and combining varieties within a crop species and among other species to make sure that production is satisfactory whichever way the weather shifts, are proven strategies of local farming communities in coping with the unpredictable. While complex, the agricultural systems not only cushion humans against the vagaries of nature, but also ensure the generation, conservation and sustainable use of crops, thus providing major support for modern agriculture the world over. The impact of the agrobiodiversity becomes global because the crops of the lower and hotter altitudes are suitable for tropical, and those from the higher and cooler altitudes are suitable for temperate, latitudes. The modernization of agriculture and importation of food are beginning to disrupt the system. The government is, however, providing supportive policies.

### *1.3 Name of person or institution responsible for the practice **or** experience*

The practice is a combined result of the work of all the farming communities of Ethiopia. Among those who have experienced the practice are the authors of this article.

*1.4 Name and position of key or relevant persons or officials involved*

No key person is involved. It is all the farming communities in the country over millennia that have developed and used this good practice.

*1.5 Details of institution*

Not applicable

*1.6 Name of person and/or institution conducting the research*

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## 2. THE PROBLEM OR SITUATION BEING ADDRESSED BY THE PRACTICE/INNOVATIVE EXPERIENCE

The Ethiopian environment is very variable in weather, temperature, moisture, altitude and topography. Ethiopia is an agricultural country, with about 85% of the population being rural (Environmental Protection Authority, 1997). In the varied and variable Ethiopian environment, a single agricultural system based on a single crop or even a small number of crops would be totally inadequate and agriculture would be stillborn **if** it depended on monocultures. Conversely, modern agriculture based on monocultures **is** being successfully adopted only in the not-so-extensive flat areas with homogenous environments, which either have high rainfall or can be irrigated.

The environmentally and culturally/ethnically variable Ethiopia thus needs a commensurate genetic diversity, and the genius of its farming communities has produced the answer.

## 3. DESCRIPTION OF THE PRACTICE/INNOVATIVE EXPERIENCE AND ITS MAIN FEATURES

The functioning of the cereal-culture complex of agricultural systems depends on its relatively large biodiversity. Thus, this study will look at this biodiversity and see how it makes it possible for the farming communities who generate, conserve and use it, to adapt their food production to the uncertainties imposed by variations in temperature, moisture (including drought conditions imposed by El Nino) and topography. This study will also touch upon the use of intra-specific variation in crops to satisfy animal production, nutritional, culinary and other demands.

### THE AGROBIODIVERSITY OF ETHIOPIA

Ethiopia has more than half of the total highland and mountain area of Africa. The Ethiopian environment, including its biodiversity, is dominated by heavily dissected and rugged extensive mountains and highlands, which are estimated to cover about 45% of the total area (over one million square kilometres) of the country.

Ethiopia is mostly in the Sahel zone, and it would have been expected to be mostly arid and semi-arid. But because of the high altitude of its landmass, it forces much rain out of the ascending and cooling air mass that goes over it. On the other hand, the north-eastern lowlands, some of which are below sea level, are in the rain shadow and are very arid.

The natural vegetation reflects in its complexity the heterogeneity of the environment. Considering their species richness, it is obvious that the montane grasslands have been in existence for a very long time. Since humans originated in these **parts** of Africa, it is also obvious that anthropogenic influences have been working for tens of thousands of years, and agriculture is believed to be at least 5,000 years old. Sickles have been found that date back as long as 12,000 years though their presence is not conclusive evidence of the existence of agriculture at the time of their making. It is safe to assume, therefore, that anthropogenic activities have contributed to the species richness of the grasslands. But even allowing for these factors, the species richness is high enough to support the assumption that edaphic grasslands were extensive even before the impact of forest clearance for crop cultivation began to be felt and the Ethiopian plateau was covered in a mosaic of forest, woodland and grassland. This has probably contributed to the range of domesticated plants by increasing the availability of crop progenitors from the grassland and ecotones between grasslands and other vegetation types, water bodies or rocky outcrops respectively; for example, *Eragrostis pilosa*, the progenitor of teff, ***Sor-***

*ghum arundinaceum,* one of the progenitors of sorghum, and the wild legumes, *Cicer cuneatum* and *Lens ewoides*.

On the whole, species richness increases towards the equator, especially when moisture stress is not great. Ethiopia is only 5 north of the equator, and its rivers water neighbouring countries all the way to the Mediterranean coast. But Ethiopia is wet where the altitude is high, and species richness decreases with altitude in spite of the increase in moisture. Therefore, Ethiopia is not one of the mega-diversity centres comparable with the countries of Central America, Southeast Asia or Central Africa. Nevertheless, Ethiopia is rich enough in biodiversity to merit attention. Based on a world estimate of about 7.5 million species of organisms present, made by the World Conservation Monitoring Centre of Cambridge in the UK, and using proportionality starting from the better known Ethiopia taxa, it has been estimated that Ethiopia probably houses about 0.5 million species (Tewolde, 1993). This is a very rough estimate but it gives an idea of the magnitude of the wealth of biodiversity.

The best appreciated biodiversity of Ethiopia is that of its crops and their wild relatives. A number of crops (e.g. enset *(Ensete ventricosum),* teff *(Erogrostis tef),* niger seed *(Guizotia abyssinica),* 'oromo/welaita dinich' *(Coleusedulis), arabica* coffee *(Coffea arabica))* were domesticated in Ethiopia. In some cases, it is not easy to decide whether given 'crops' are really domesticated as they are found growing more extensively in the wild than in farmers' fields (e.g. 'ensosila' *(Zmaptienstinctoria),* 'korerima' *(Aframomum korarima),* 'anchote' *(Coccinea abyssinica)).* One feels that some species are wild though they are found cultivated for specific purposes (e.g. *Arundinaria* bamboo, *Hyparrhenia* thatch grass). There are also a number of plants grown in small patches and home gardens which are not generally recognized as crops, but which are dependent on human care for their survival. These include *Arundo donax,* used for fencing and furniture, and others which are perfumes and/or fumigants like 'ades' *(Myrtus communis)* and 'rehan' *(Artemisia rehan).* **A** number **of** crops are believed by many **to** have been domesticated in Ethiopia though there is no unanimity on this (e.g. finger millet *(Eleusine coracana),* sorghum *(Sorghum bicolor),* sesame *(Sesamum indicum),* chickpea *(Cicer arietinum)).* Of the many introduced crops, some now have their major surviving gene pools in Ethiopia (e.g. barley, durum wheat, linseed). Some of these, e.g. field pea, have very distinct genotypes found nowhere else.

For some very old crops like the primitive wheats, *Triticum dicoccon, T: polonicum* and ***T:*** *speltum,* Ethiopia is one of the few refuges where they have survived. The treatment of *Triticum* for the Flora of Ethiopia (Phillips, 1995) also recognizes an endemic species of tetraploid wheat, ***T:*** *aethiopicum,* which is similar to, and has often been confused with, ***T:*** *durum*, which also occurs in Ethiopia. The number of crops cultivated and their wild relatives in Ethiopia is more than one hundred (Edwards, 1991) and, excluding herbs and spices, it is about sixty in the cereal-dominated agricultural systems complex. Several of these crops are also grown in the enset-dominated and yam-dominated polycultures, but there are some crops peculiar to those systems.

## THE CEREAL-DOMINATED AGRICULTURAL SYSTEMS COMPLEX

The highlands between 1,500 m and 3,500 m above sea level (a.s.1.) in northern, central and eastern Ethiopia support variants of cereal-dominated agricultural systems. Pulses, oil seeds and some vegetables and fruits are also produced.

The wild herbs, trees and shrubs found in the uncultivated areas often yield food as well and the distinction between domestic and wild plants becomes blurred.

When not under stress from excessive population pressure, the arable land is fallowed at regular intervals. In the fertile areas, fallowing may not be required for up to seven years, while in the poorest soils, fallowing may be required every other year.

**As** a rule, a given crop is not grown in successive years on the same field. This rotation helps keep weeds down and reduces the demand for hand weeding. It also varies the demand on nutrients from the soil helping in keeping it fertile and healthy. When the crops grown are pulses, the magnitude of restoration of fertility is substantial, owing to the fixing of nitrogen, and can lengthen the time interval between fallows or even altogether eliminate the need for fallowing.

Though the animals obviously scatter their dung/droppings as they move about during the day, thus helping fertilize their grazing areas, they are penned at night. The manure from the night dung is used for fertilizing fields where cereals are to be planted, though where wood is in short supply, using it as fuel competes with this purpose.

This system of agricultural production integrates animal and plant production, crops and wild plants, and arable and non-arable land into one complex – an agroecosystem.

The complex has developed mechanisms of adapting itself to variations in temperature (as associated with altitude and seasons) and moisture and unpredictability of environmental variations. Variability in agrobiodiversity, making it possible to combine complementary planting material, is at the heart of the range **of** adaptations.

## ADAPTATION TO TEMPERATURE VARIATIONS

Altitude is an easily measurable variable which can be taken as a good correlate of temperature. Table 1 gives a partial list of the crops grown in the cereal-dominated complex under the altitudinal and moisture regimes found in Ethiopia.

In the area under consideration, the highest and coldest altitudes cultivated (2,300-2,800/3,500 m a.s.1.) are dominated by barley, though some wheat may be found near the lower limits. In some areas in this altitudinal zone and in the zone below it, the barley is adulterated/mixed with the endemic semi-domesticated Abyssinian oat, *Avena abyssinica,* and the crop is a mixture of the two species. Since the early 1980s,European oats *(Avena sativa)* has been spreading and replacing barley in some areas, particularly where rainfall is higher and more reliable. Originally introduced as a forage crop, European oats has been spontaneously adopted by farmers because, in contrast to most varieties of barley, the grain is easily threshed and the process of making acceptable 'injera' (the traditional soft, flat bread) is thus less laborious. The plants produce good straw for animal feed and thatching. Faba bean is the only pulse and linseed, the only oil crop grown at these altitudes.

In the cool areas between 2,300 and 2,800 m a.s.l., barley and wheat are the important cereals, with a specially adapted farmers' variety of teff being important in the less moist areas. Faba bean, field pea, lentil and, to some extent, grass pea are the pulses grown. This zone is marginal for the traditional oil crops, though both linseed and niger seed may be found, and safflower *(Carthamus tinctorius)* is grown at the lower limits. However, recently introduced and adapted rape seed *(Brassica rapa)* does very well. It has not traditionally been used as an oil crop for food but its use as a source of food oil for the urban areas is now growing. The traditional brassica oil crop, 'gomen zer', consists of two different species: a many-branched, small-leaved variant of Ethiopian kale *(Brassica carinata)* and *Erucastrum abyssinicum.* The seeds are crushed and used to grease the earthenware hot plate for baking 'injera'.

It is at this altitude that 'ensosila' *(Zmpatiens tinctoria),* a plant used for cosmetic purposes and usually collected from the wild, has been seen being cultivated, indicating the process of crop domestication taking place. 'Koshim' *(Dovyalis abyssinica),* rose hip *(Rosa abyssinica),* 'injore' *(Rubus* spp.) and 'agam' *(Carissa edulis)* are among the wild fruits eaten. There also are a number of weedy and **wild** species eaten as vegetables, e.g. *Amaranthus* spp., *Haplocarpha schimperi.*

The greatest range in crops is grown between 1,900 and 2,300 m a.s.1. The list of the important annual crops includes barley, teff, wheat, sorghum, maize, finger millet, pea, chickpea, lentil, fenugreek, grass pea, linseed, niger seed, safflower and rape seed. Haricot beans are often cultivated mixed with sorghum and maize. Bread wheat is a relative new-comer which is expanding in this zone primarily to supply wheat to the modern bakeries in towns. Cowpea is sometimes found at the lower altitudes in drier areas of this zone. It becomes more important at altitudes below 1,900 m. Peach, grapes, lime, pomegranate, citron and sour orange are fruit trees which were introduced in the distant past. Other perennial crops recently introduced include plum, guava, loquat, mulberry and strawberries, among others. Banana can also be found at the lower altitudinal limit in this zone. 'Wanza' *(Cordia africana)*, 'enkoy' *(Ximenia americana)* and figs are some of the wild fruit trees occurring extensively in this zone. Many wild herbs, e.g. *Uritica simensis* (nettles), *Haplocarpha schimperi, Amaranthus* spp., are eaten as vegetables, but mostly only in times of food shortage or for special nutritional purposes.

In the hot lower highlands (I,500-1,900 m a s l.), sorghum, teff, maize, finger millet, sesame, coffee and khat are the main crops. Traditionally, cowpea has been cultivated with maize and sorghum, but it is being replaced by haricot bean. Bambara groundnut is sometimes found in the wetter western parts of the country; groundnut is a relatively new introduction which is expanding in drier areas. Bananas and oranges are traditionally grown fruit trees, but it is introduced varieties which are now grown in commercial farms, with the traditional varieties being restricted to home gardens. Several fruit trees have been introduced recently, e.g. avocado, custard apple, bullock's heart, guava, grapefruit, mandarin. There are many wild fruit trees, e.g. figs, 'geba' *(Zyziphus spina-christi)*, desert date *(Balanites aegyptiaca)*, 'dokma' *(Syzygium guineense)*, 'enkoy' *(Ximenia americana)*. Wild herbs, e.g. *Amaranthus* spp., are also gathered and eaten during the rainy season.

A major factor complicating the effect of temperature is seasonality. At the higher altitudes, crops grow well in the summer when the rains come. Sometimes, autumn cold sets in before they have completed their growing cycle and they may be damaged by night frost. This is especially a problem in vertisol areas since many of the crops are planted late, when waterlogging ceases to be a problem, and may thus be caught out by frost. The most frost-resistant native crop is barley, but it does not grow well on vertisol.

## ADAPTATION TO MOISTURE VARIATION

The varieties of the crops grown by farmers can mature in as short a time as 45 days while others require over 180 days. The choice of a crop or of a variety is strongly influenced by the rainfall regime of the area although small-scale irrigation based on diverting streams is also widely practised, but is generally restricted to a few selected crops. Crops require a longer growing season as the altitude increases, and hence temperature decreases, and vice versa. Thus, the fastest-growing varieties are found in the warm to hot semi-arid areas. An extreme example is teff *(Eragrostis tef),* which has farmers' varieties that can mature in 45 days using moisture accumulated from flash floods. This same crop also has farmers' varieties which require up to 180 .days to mature.

The rainfall regimes of the areas where the cereal-dominated agrobiodiversity complex is found vary from unimodal to bimodal, with reliability decreasing as the rainfall regime becomes more bimodal. The wetter western highlands have a generally unimodal rainfall system of five or more months, with the rains starting in March, April or May and ending in September or early October. The central and eastern parts of the main highland mass have a bimodal rainfall pattern, with the intensity and reliability decreasing eastwards and northwards. However, some parts **of** the eastern escarpment also receive a third moist season – that which comes from the wet winter rain system of the Middle East – giving rain and/or heavy mist in December and January.

On the central and northern landmass, the two rainy seasons of the bimodal rainfall system are separated by a dry period which can be as short as two weeks or as long as five to six weeks. The dry gap increases in length from west to east and from south to north. When the spring or small rains materialize, long-growing season crops (sorghum, finger millet, some varieties of teff) are planted with the expectation that soil moisture and their adapted physiology will enable them to survive through the dry gap into the main summer rainy season. When the small rains fail or the gap between rainy seasons is too long for the crops to survive, short-growing season crops are planted. Short season crops, e.g. barley, are also grown during the short rainy season in the hope that they can be harvested in the dry gap between the rains. This is an important food-security strategy as it provides grain to households during the main rainy season at a time when food stocks are generally at their lowest. After the barley is harvested, a second crop can be grown or the field fallowed and grazed through the main rains. Other crops, which are often grown deliberately to fill this food gap towards the end of the rainy season, are maize *(Zea rnaiz)* and pumpkin *(Cucurbita* spp.).

Some of the long rainy season crops are planted under irrigation early enough, even when the spring rains fail, so they can be transplanted to grow to maturity during the main rains. This is especially true of red pepper *(Cupsicum annuum)* and, of course, tree seedlings. Onion ***(Allium** cepa)* and garlic **(A. *sativum)*** are also sometimes transplanted, but more often, they are grown fully under irrigation. With the development of small dams, maize is becoming widely planted under irrigation to provide fresh cobs **as** a quick food in urban areas, as well as to fill the food gap in the main rains for rural families.

Changes in the rainfall pattern, which can probably be attributed to climate change, have been reported to be affecting the choice of farmers' varieties to be grown. An example of this has been reported (Biodiversity Institute staff, personal communication) by farmers near Adi Grat in Northern Ethiopia. These farmers said that in the past they cultivated a barley variety called 'atena' which would start growing in the spring (small) rains, would be subjected to the somewhat long intervening dry season, and, when the main rains arrived, would revive, tiller profusely and thrive to maturity. They now maintain that either the spring rains fail or, when they come, the 'rainless' period which follows them is not dry enough to stimulate 'atena' into a good summer tillering and growth.

The dry sub-humid and semi-arid areas are those with the most erratic rainfall in both distribution and amounts. Farmers often insure themselves by planting a mixture of wheat and barley, which they treat as one crop, called 'hanfets'. If the rainfall is heavy, it favours the wheat, and if it is light, the barley does better. The performance of both wheat and barley under reduced moisture is improved by an appropriate choice of farmers' varieties. The drought-resistant character of barley is ensured by a process of growing and selecting the seed under moisture stress. Every year at the end of the main summer rains, an appropriate variety is sown, which has to grow on residual soil moisture, completing its growth cycle under the intensely dry conditions that come after the rainy season. This selects for barley variants that perform well under reduced-moisture conditions. Barley which has been thus selected is called 'sa'sa' and the seed is kept for planting in the following year's summer rainy season.

At higher altitudes, a mixture similarly used is barley and Abyssinian oats, with the oats being more tolerant of wetness than the barley. In some areas, the oats is not considered as a crop but as a tolerated weed while in others, the mixing is said to be more deliberate. The use of Abyssinian oats thus shows another plant being domesticated into a crop. At lower altitudes, pearl millet can be found intercropped with sorghum; pearl millet does better if the season is drier while the sorghum does better when it is wetter. An additional reason for this intercropping is that the taller sorghum seems to provide some protection for the pearl millet from quelea birds.

A striking feature of many of the cereal crops is the very rapid transition of the crops from flowering, which usually coincides with the end of the rainy season, to seed set, filling and full maturity. This is an adaptation to the very sudden drying-up of the environment under the influence of the dry season wind, which blows from the deserts of Arabia.

The southeastern landmass has a different bimodal system, with rainy seasons in April-May and October-November separated by long dry periods. Either one or both of the rainy seasons may be long and intense enough for crop production. However, in many areas, neither season is long enough. For these reasons, only short season crops are found grown in these parts of the country. The extensive flatter areas of Bale and Arsi which have such bimodal rains, have been found to be the most suitable areas in the country for growing introduced bread wheat and rape seed.

Peasant farmers note the way the rainy season sets in and consider other variables as well to predict whether the rains are going to be heavy or light. However, the reliability of their predictions has not been scientifically evaluated. Nevertheless, based on their prediction, the farmers choose the species and varieties of crop to plant and when to plant them. From Table 1, it can be seen that the crops are best adapted to one or two of the rainfall regimes, but specially selected varieties are developed to satisfy specific uses.

Barley, sorghum, maize and teff are the most widely adapted cereals; faba bean and haricot bean, the most widely adapted pulses; and linseed and niger seed, the most widely adapted oil crops. All these crops have differing adapted farmers' varieties. The table also shows that most crops of the cereal-dominated agrobiodiversity complex are well suited to a dry sub-humid moisture regime, i.e. a growing season of 90 to 120 days.

## ADAPTATION TO TOPOGRAPHY

Ethiopia is mountainous, and topography is a very important factor in agriculture. Many of the impacts of topography are caused by moisture. It is thus often the moisture-loving crops that are grown in the valleys and the moisture-stress-tolerant ones which are planted on the slopes.

Many of the valleys and plains have vertisols. This makes them easily waterlogged. Thus, the moisture-loving crops intolerant of waterlogging, e.g. maize, cannot grow on these heavy clay soils. On the other hand, some crops of the dry sub-humid and semi-arid conditions are planted in these heavy soils at the end of the rains. This strategy avoids the problem of waterlogging, but treats the sub-humid conditions as if they were semi-arid. For example, grass pea and chickpea are pulses, which are well adapted to semi-arid conditions. However, in Ethiopia, they are mainly grown on the wet vertisols, mostly planted late so that they mature on residual moisture. With climate change causing the semi-arid conditions to be severe, chickpea is now also grown on well-drained slopes in the long rains.

The vertisol areas themselves are becoming more easily managed. On the one hand, this is a result of new management practices and tillage equipment being introduced to the farmers. On the other hand, there is overall climate change and a reduction in rainfall amounts and duration. As a result, some farmers' varieties which were previously grown on the residual moisture of the vertisols are being replaced by other farmers' varieties and improved modem varieties from the research and development system. A notable example of a farmers' variety that is disappearing is the wheat called 'kinkinna'.

A notable feature of the traditional management of these soils was that they were ploughed late in the rainy season. Now they tend to be ploughed earlier and are bare when the first rains fall. There were also many valley bottoms, which were left uncultivated for grazing. The increasing pressure for cropland has encroached on these grazing areas so that they are disappearing fast in many parts of the country. The combination of cultivating these valleys and the shift to ploughing them at the beginning of the rains has exacerbated soil erosion in general, and gully erosion in particular. This, in turn, is helping revive the old practice of soil bunding and terracing.

It is understandable that it is the valley bottoms and other relatively flat areas which are the most important for crop production. However, fieldwork with farmers near Asmara in Eritrea (which is part of the same cereal-based agrobiodiversity system as in Ethiopia) has shown that these areas depend on neighbouring rugged areas for their supply of good seed.

The flat areas are intensively sown with different farmers' varieties right next to each other. There is a free flow of genes between these varieties *so* that the distinctive traits for which they were originally selected are reduced or disappear. These areas can also suffer from mass attacks by pathogens and pests, somewhat reminiscent of the problems with modern, genetically uniform, varieties. Near Asmara, the biggest problem was rust. Seed harvested from these fields tended to lose the genetic heterogeneity of the selected farmers' varieties and thus became more susceptible to mass attack so that after some years, the farmers needed to renew their seed source.

The rugged areas consist of a patchwork of small, often very small, fields with a corresponding range of crops and varieties of crops. These fields are not contiguous; banks, bunds and patches of natural vegetation and rocks separate them. Several crops, but not wheat and barley, have wild relatives growing as weeds in the same fields. This makes it easy for farmers to keep the varieties of the same crop distinct. However, it is possible for genetic exchange to take place between farmers' varieties and their wild relatives. Thus, the seed from the crops grown in these small, isolated and environmentally diverse fields is able to retain a higher genetic diversity than that taken from the more extensive and uniform fields on the vertisols. The complementarity **of** the highly dissected and diverse fields on the rugged sloping areas with the potentially more productive and more uniform valley and plain areas for maintaining agrobiodiversity along with improved productivity for food security is a key feature of the traditional agricultural system which requires further systematic study and support, probably also further development.

## AGROBIODIVERSITY AND MEETING THE DEMAND FOR FEED

Agriculture in Ethiopia integrates crop and domestic animal production. Domestic animals are central to crop production because of the use of cattle as drought animals for ploughing as well as a source of milk, meat and skins; donkeys, mules and horses as pack animals for transportation in the difficult broken-up highland terrain; and small ruminants for meat and skins, as well as the use of animal manure as fertilizer. An increase in crop cultivation, therefore, necessarily involves a commensurate increase in domestic animal production. Meeting the food needs of an increased human population therefore entails the need to meet increased feed demand, and all from the same biomass.

Given this condition, it is, on cursory look, difficult to understand that such a complex agricultural system has failed to develop a feed-production component: there is no crop specifically developed for feed. A closer look, however, shows that the agricultural system complex does cater for feed production in two ways:

(a) The uneven terrain means that farmland is rarely far away from uncultivable slopes or uncultivated valley bottoms where domestic animals graze.

(b) Crop residues, on the whole, are sufficient to supplement grazing in the uncultivable slopes. The crops are selected for their production not only of human food, but also of animal feed. For example, teff ***(Eragrostis** tef)*, the most widely grown cereal, is not only the most preferred cereal for human consumption, but also the best animal feed. Scientific investigations (Tsige-Yohannes, 1998) have shown that teff straw "is similar with most roughage, even with the ones considered quality". Another crop important for feed is sorghum, which has a large diversity in Ethiopia. In the erratic rainfall areas of Northeastern Ethiopia, the farmers have developed varieties that survive long **dry** spells, keep growing for over six months, and produce food and feed at the same time. With the long dry spells in mind, researchers produced modern short-stalk varieties that mature in less than half the time. Adoption of the new varieties has been very poor in spite of the more reliable seed production because of the poor feed production.

Crop biodiversity in Ethiopia, therefore, caters not only for human use, but also for domestic animal feed. The traditional methods of intensifying agricultural production have, understandably, addressed the problem of feeding humans and domestic animals together. One problem with further intensification of agricultural production is thus the fact that it has been disregarding the animal-feed component of the traditional systems.

## THE USE OF AGROBIODIVERSITY IN MEETING NUTRITIONAL, CULINARY AND OTHER NEEDS

The agrobiodiversity of Ethiopia has been so domesticated/adopted that each moisture and temperature regime has cereals, pulses and oil crops growing in it, ensuring a balanced diet (see Table **l).** The standard Ethiopian meal in the cereal-dominated areas consists of bread made from a cereal dipped in a spicy semi-liquid mixture made of pulses, oil and water, and often also of vegetables.

**A** given crop often has different varieties for specific culinary requirements. For example, a specific variety of sorghum (‘qintish’) is grown for the sugar content of its cane, another (‘zengada’) for brewing, another (‘fendisha’) for making the sorghum equivalent of popcorn, and many other varieties for making porridge, bread, or simply for boiling (as is usually done with rice) and eating. Varieties also exist for resisting bird attacks either because they are bitter (e.g. ‘zengada’) or, as is the case with the majority of varieties, because they have compact inflorescence (seed-bearing heads).

Sometimes, the specifically bred varieties have to be treated in a specific way to give the required result, *e.g.* ‘zengada’ is alkali-treated by mixing it with moist ash and keeping it overnight to enhance its brewing quality, and ‘fendisha’ is very briefly treated with hot water to maximize its popping tendency.

On the whole, the crops have specific varieties for maximizing suitability for specific purposes. Similarly, some crops are preferred for some uses. For example, teff, with its very low gluten content, is the most preferred cereal for making the soft, flat, thin and flexible staple bread peculiar to Ethiopian cooking, called ‘injera’, and wheat, with its high gluten content, is the most preferred grain for making the local equivalent of European bread, called ‘dabo’, used mostly for breakfast and snacks. These two cereals are the least exchangeable in the making of the two types of bread, wheat making the worst ‘injera’, and teff making the worst ‘dabo’.

## 4. DESCRIPTION OF THE INSTITUTION RESPONSIBLE AND ITS ORGANISATIONAL ASPECTS

It is the whole society of Ethiopia with its many cultures over many millennia that has been responsible for the creation of the flexible systems complex of agricultural production based on a wide range of agrobiodiversity. Describing the various cultures and their social, political and economic institutions would be too big a task to undertake here.

The institution responsible for undertaking this study is the Institute for Sustainable Development, a small non-governmental organization situated in Addis Ababa. It has a board of directors and four scientists. It also uses consultants to do specific studies. It gets its funding from donors, mainly through international non-governmental organizations, including the Third World Network of Penang, Malaysia and the Gaia Foundation of London, UK.

## 5. PROBLEMS OR OBSTACLES ENCOUNTERED AND HOW THEY WERE OVERCOME

Not applicable.

## 6. EFFECTS OF THE PRACTICE/INNOVATIVE EXPERIENCE

With nearly 60 million people, Ethiopia is, after Nigeria and Egypt, the most populous country in Africa. About three-quarters of its export earnings come from agriculture, and about 80% of its population is deployed in agricultural activities. Except for cotton, sugar and fruits for urban consumption, very little is produced through modem mechanized agriculture. Virtually all food is produced by the farming community based on the smallholder traditional agricultural system, which accounts for 95% of all agricultural output (Environmental Protection Authority, 1997).

Following some colonial encounters with the Portuguese in the 16th century, Ethiopia lived isolated from the rest of the world, beating off Ottoman and European colonialism until it was forcefully, though only partially, integrated with the rest of the world during the Second World War. Even now, its integration is only partial, and its economy caters mostly for the internal market.

Ethiopia suffered a three-decade-long civil war, which ended only in 1991. Even though, when coupled with the El Nind effects, the disruptions caused by the war produced famines in some areas, e.g. in 1984-85, the relatively large population fed itself because the agricultural system was decentralized, community-based and largely independent of imported inputs.

Following the re-establishment of peace in 1991, Ethiopia has moved very quickly towards food self-sufficiency and towards the development of industries based on agricultural products. Even following the seriously negative impact of **El** Nind and the great reduction **of** rainfall **in** the 1997 rainy season, the food deficit has been small. Now that, in the main rainy season of 1998, the rains are good, a food surplus will be expected and, with the further development of storage and transportation infrastructure, Ethiopia is looking forward to food self-sufficiency even in El Nind years.

## 7. SUITABILITY AND POSSIBILITY FOR UPSCALING

A lot of scientific knowledge, both on the crop species and on environmental management, has been acquired globally in general and in Ethiopian research institutions in particular, e.g. in the Institute of Agricultural Research in Addis Ababa and in its various stations. Some of this knowledge may disrupt the well-balanced traditional systems, e.g. the excessive use of chemical fertilizer and the use of pesticides in place of, or meant to supplement, the organically-based soil fertility management systems and the diversity-based pest management systems. But there could be innovations which complement the existing practices and improve the productivity of the systems, e.g. composting, the use for fertilizer of not only animal dung but also animal urine as well as the improvement of their management, and improvements in the use of leguminous plants. By focusing research for increases in production on the whole system rather than on monocultures, agricultural production in Ethiopia can continue to increase sustainably.

## 8. SIGNIFICANCE FOR (AND IMPACT ON) POLICY-MAKING

The Ethiopian farmers have long resisted efforts at simplistic approaches to improvements of agricultural productivity based on single “miracle” steps, e.g. the use of varieties which increase seed yield but reduce straw yield, chemical fertilizer which they claim habituates the land like a narcotic, or pesticides which, on the immediate basis, increase crop production and eliminate honey production – Ethiopia is Africa’s biggest per capita honey producer. Such resistance was, in the past, attributed to ignorance.

The assumption that farming communities are ignorant, though eroding quickly, still lingers on. Nevertheless, the Ethiopian Government has now realized the positive attributes of the agricultural systems of farming communities and it has been developing policies and strategies that try to build on the strengths of these farming systems. The international scene is, however, not conducive to the development and implementation of these policies and strategies.

## INTERNATIONAL ISSUES INVOLVING BIODIVERSITY

Biodiversity has always been taken by anyone who wanted to take it whenever he/she wanted. The knowledge and technology of using it was also passed on freely.

But following the development of intellectual property rights (1PR)-protection legal regimes in the industrialized West, originally aimed at mechanical inventions, Breeder's Rights on plant varieties and later patenting of living things became the global norm. There are now thousands of crop and ornamental plant varieties that fetch royalties for corporations. The trend of corporate patenting of biological materials will accelerate with the implementation of the World Trade Organization's agreement on IPRs.

The Convention on Biological Diversity also accepts the protection of such individual IPRs but not the unwritten community rights of the South. However, this was rectified by the 4th meeting of the Conference of the Parties in Bratislava in 1998, and the Convention itself stipulates that the owners (countries of origin) of biodiversity have the right to benefit from the commercialization by others of their biodiversity.

There is, therefore, an obvious need for Ethiopia to develop legislation to regulate access to its biodiversity, and to protect the community rights of its hunter-gatherers, pastoralists and peasant farmers who have accumulated innovations in the sustainable use and conservation of biodiversity. A legislation to this effect is now being drafted in Ethiopia, and the Organization of African Unity has recommended such a draft law for adoption throughout Africa. It is also working towards an African Convention.

The absence of such legislation makes Ethiopia forego the benefits it could have obtained from the biodiversity and innovations of its communities. This, in turn, reduces the possibility of raising the visibility of the usefulness of biodiversity and hence also the motivation to use it sustainably and to conserve it.

## ETHIOPIAN GOVERNMENT POLICY AND INSTITUTIONAL ARRANGEMENTS FOR BIODIVERSITY CONSERVATION

The macro-level policies of the Government of the Federal Democratic Republic of Ethiopia give biodiversity conservation sufficient attention. The Environmental Policy of Ethiopia, which was approved in April 1997, has a section specifically dedicated to biodiversity, and other sections which deal with sectors which impinge on biodiversity. But the micro-level policies and the legislation required to put these policies into effect have not yet been fully developed though efforts are underway. An overall environmental framework legislation and an environmental impact assessment legislation, in both of which biodiversity figures prominently, a biodiversity access, benefit sharing and community rights legislation, and a legislation on biosafety from genetically modified organisms and from alien species have been or are being drafted, though none of them is yet law.

Ethiopia has a Seed Industry Policy which is aimed at helping the farmer increase agricultural production through the use of improved seed when necessary, but keeps this to the minimum possible and ensures that high-yielding farmers' varieties continue to be used and encourages the use of native agrobiodiversity in the development of varieties.

In this context, it states, "... The accelerated genetic erosion of local landraces and farmers' varieties as a result of aggressive promotions of improved exotic varieties will be minimized or checked through implementing balanced developments in the areas of plant genetic resources conservation, and seed production and supply," and "The national crop breeding programs will, as much as possible, be based on the principle of using the indigenous crop genetic resources and the agricultural systems as the foundation of the crop improvement work ...".

One important implication is the decoupling of seed and other inputs so as to prevent the giving up of existing genetic resources in order to have access to agricultural inputs. This is done by preventing "private (domestic and foreign) seed enterprises" from having "a monopoly of the production and supply of seed of any one crop" and by promoting the active participation of farmers in the seed industry and the sustainable use of local cultivars. To achieve this, there is a rigorous system of seed testing, approval and registration of improved varieties which takes several years, and a requirement that all varieties, locally developed or imported, be subjected to it.

## 9. POSSIBILITY AND SCOPE OF TRANSFERRING TO OTHER COMMUNITIES OR COUNTRIES

The complex of community-based agricultural systems of Ethiopia can be used as models for developing sustainable agricultural systems in the ecologically unstable monoculture-based agricultural systems of the industrialized world and many of the developing countries. This would make world agriculture robust, with few fluctuations, and the world more food-secure.

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**TABLE 1: A partial list of the crops of the cereal-dominated agricultural systems complex with the most suited main crops produced under different environmental conditions**

| | 1500-1900 | 1900-2300 | 2300-2800 | Over2800 |
|---|---|---|---|---|
| **Humid** | | | | |
| Cereals | Finger millet, Maize, Sorghum, Teff | Finger millet, Maize, Sorghum | Area Insignificant | |
| Pulses | Lupin, Lima bean, Haricot bean | Lupin, Haricot bean | | |
| Oil Crops | Niger seed | Niger seed, Linseed | | |
| **Sub-Humid** | | | | |
| Cereals | Finger millet, Maize, Teff | Finger millet, Maize, Barley, Teff, Wheat | Oats, Barley, Wheat | Oats, Barley |
| Pulses | Chickpea, Cowpea, Haricot bean | Chickpea, Cowpea, Haricot bean, Faba bean, Grass pea, Pea | Chickpea, Faba bean, Grass pea, Pea | Faba bean, Pea |
| Oil Crops | Niger seed, Safflower | Linseed, Safflower, Niger seed, Rape seed | Linseed, Rape seed | Rapeseed |

Table 1 (continued)

| | | | | |
|---|---|---|---|---|
| **Dry Sub-Humid** | | | | |
| Cereals | Sorghum, Teff, Wheat, Maize | Sorghum, Teff, Wheat, Maize | Barley, Oats, Sorghum,Teff, Wheat | Barley, Wheat, Teff |
| Pulses | Chickpea, Cowpea, Haricot bean, Groundnut | Field pea, Lentil, Chickpea, Grass pea, Groundnut | Faba bean, Field pea, Lentil, Chickpea, Grass pea | Faba bean, Field pea, Grass pea |
| Oil Crops | Sesame, Niger seed | Linseed, Rape seed, Safflower, Niger seed, Sesame | Linseed, Niger seed, Rape seed | Linseed, Rape seed |
| **Semi-Arid** | | | | |
| Cereals | Finger millet, Sorghum, Teff, Maize | Finger millet, Sorghum, Teff, Wheat, Barley | Barley, Sorghum, Teff, Wheat | Barley, Wheat, Teff |
| Pulses | Cowpea, Haricot bean, Groundnut | Chickpea, Groundnut, Lentil, Grass pea | Faba bean, Lentil, Chickpea, Grass pea | Faba bean, Lentil, Grass pea |
| Oil Crops | Sesame | Linseed, Sesame, Rape seed | Linseed, Rape seed | Linseed, Rape seed |