INTEGRATING INDIGENOUS AND MODERN AGRICULTURAL TECHNOLOGIES IN THE DROUGHT-PRONE AREAS OF ETHIOPIA

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INTRODUCTION

Indigenous agricultural practices refer to the practices, skills and techniques that were developed by farmers over generations as opposed to the global agricultural technologies generated by the modern network of research institutes in the last hundred years. Indigenous practices are dynamic in the sense that they are continuously adapted to the changing circumstances and environmental conditions by each generation as it is passed on to the next. Because they are dynamic, indigenous practices can be easily adapted to unpredictable environmental changes. These traditional agricultural practices are productive, stable and, therefore, maintain a considerable degree of sustainability provided that they are not faced with a high population pressure (Radclift, 1987). The American Society of Agronomy (1988) cited in White et al. (1994, p. 232) defines sustainable agriculture as "one that, over the long term, (i) enhances environmental quality and the resource base on which agriculture depends, (ii) provides for basic human food and fiber needs, (iii) is economically viable, and (iv) enhances the quality of life for farmers and society as a whole.". Indigenous practices have a considerable degree of sustainability because they have been developed in line with the laws of natural ecological systems (eg. crop diversity, self reliance, stability, etc.) and within the limits of the farmer's acquired or inherited culture and knowledge. Thus, integration of indigenous agricultural practices with newly introduced technologies increases the sustainability of modern agricultural management systems.

In this paper I will try to establish the need for such integration in the drought-prone areas of northern Ethiopia (i.e. Welo, Tigray, North Shewa and Gondar). I will illustrate my points using the South Welo Zone as a case study. First, I will assess the environmental conditions of the zone and try to identify the major constraints to crop production. This is followed by identification of the strengths and limitations of both the indigenous practices and the modern technologies, and explanation of how the two systems can be integrated to develop a more sustainable agricultural management system.

THE SOUTH WELO ZONE

Description of the Area

South Welo is a zone characterized by dissected topography, rugged terrain and highly variable climate. On the highlands where rain-fed crop cultivation is the norm, altitude ranges from about 1500 to slightly above 3500 meters above sea level with corresponding hot and semi-arid to cold sub-humid climate. Mean annual temperature decreases from about 20°C, at elevation of about 1650 m (as in Bati town), to about 16°C at about 2550 m (as in *Desse*) and falls to less than 10°C at elevations of above 3200 meters (Belay, 1995). Annual rainfall records range from 850 mm in Bati town (1650 m a.s.l.) to 1200 mm in Boru Meda (2750 m a.s.l.). Rainfall is expected to be above 1200 mm at altitudes of above 3000 m. This temperature and rainfall variability has caused the differentiation of the highlands into belts with distinct agro-climatic zones -- traditionally recognized as *kolla*, *woina dega* and *dega* (Table 1). The rain extends over 5 to 7 months in the *dega* and *woina dega* and 4 to 5 months in the *kolla* zones. In all cases it is bimodal with the little rain ("belg") from March to May; and big rain ("meher"), June to October.

The rainfall regimes are generally characterized by wide annual variations. For example, annual rainfall recorded over 10 years (1983-1993) in Maybar (*dega* zone), 14 km SSE of Desse, ranged from 721 mm in 1984, to 1489 mm in 1993 – ie., 60 and 121 percent of the mean annual value, respectively (Table 3). Hence, considerable year to year rainfall variation is one of the typical characteristics of the zone and as a result there is serious uncertainty among farmers as to amount and timing of rainfall each year. Variability generally increases with decreasing rainfall and hence is expected to be much larger in the *kolla* compared to the *dega* or *woina dega* zones.

Table 1. Agroclimatic zones of northern Ethiopia

	Agro-climatic zones			
Characteristics	*Kolla*	*Woina dega*	*Dega*	*Wurch*
Altitude (m)	1500-1800	1800-2400	2400-3500	>3500
Temp. (C)	18-20	15-18	10-15	<10
Rainfall (mm)	300-900	500-1500	700-1700	>900
Dominant crops	Sorghum, maize	Teff, maize, wheat	Barley, wheat	Barley

Source: Adapted from Amare (1984)

Table 2. Average annual precipitation (mm) for Bati, Hayk, and Maybar meteorological stations

Station	Alt. (m)	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Bati	1660	41	47	39	**83**	50	19	**192**	216	85	31	23	26	852
Hayk	2050	39	66	**111**	**111**	74	30	**285**	**284**	**111**	47	24	23	1205
Maybar	2500	38	**70**	**96**	**113**	**103**	28	**233**	**288**	**141**	51	20	42	1221

Note: The bold figures indicate rainy months, i.e., rainfall of above 50 mm.
Source: Adapted from Paris (1985), Krauer (1988) and SCRP (1996)

Table 3. Annual variability of precipitation (P) (mm) in Maybar (2545 m) (1982-1993)

Year	1982	1983	1984	1985	1986	1987	1988	1989	1992	1993	Mean
P	1432	1122	721	1093	1465	915	1347	1407	1118	1489	1211
X (%)	118	93	60	90	121	76	111	116	92	123	100

Note: X refers to percentages calculated against the mean annual rainfall. Also note records were not conducted properly in 1990/91 because of political problems in the area.
Source: Adapted from SCRP (1996)

Table 4. Percentage of land by depth in selected catchments of South Welo.

Soil depth (cm)		Percent of total catchment area Derekolli	Nibo	Gido	Wurgo	Av.
<30	Very shallow	38	30	34	52	38
30-50	Shallow	13	16	19	13	15
50-100	Moderately deep	24	19	11	8	16
≥100	Deep to very deep	25	35	37	28	31

Note: Depth classes are defined according to Guidelines for Soil Profile Description (FAO, 1990)

South Welo constitutes one of the densely settled areas of Ethiopia. The population density is particularly very high when considered in relation to the subsistence agriculture, low level of technology and very low levels of soil productivity. This has led to severe demographic pressure and subsequent destruction of the vegetation and degradation of the soil resources. According to some estimates, more than 75 percent of the soils in the Welo highlands have depths of less than 30 cm (Hurni, 1993, 1988). My study, conducted in representative sub-catchments of South Welo, suggests that of the total land area about 38 % has soil depth of less than 30 cm while 43% is less than 50 cm (Belay, 1998b). The natural forest in South Welo is also completely removed. Estimates indicate that the area currently covered by natural forests is only 11,368 ha, and this accounts for only 0.5 percent of the zone. The average holding of cultivated land is estimated at 0.63 ha/family (Department of Planning, 1993). Currently, all the land suitable for rainfed crop cultivation is converted to farmlands and hence further increase in cultivated land is not feasible.

Agriculture in South Welo involves subsistence production of a variety of crops and of livestock. Double cropping is widely practiced in the *dega* and *woina dega* while multiple cropping is more intensively practiced in the *kolla* zones. However, crop yield is kept very low because of a number of factors. Data collected in Maybar suggest average yield of 22.0, 15.3, 18.6 and 10.4 qt/ha, for maize, barley, horse beans and teff, respectively (SCRP, 1996). Yields of lentils and sorghum are estimated at 4 and 10 qt/ha, respectively (Department of Planning, 1993).

Major Constraints to Crop Production in South Welo

It hardly needs to be restated that there is an urgent need for increased food production in Ethiopia in general, and the drought prone areas in particular. However, because most of the arable land in these areas is currently under cultivation, crop production can be boosted only through intensification. There is considerable scope for increasing crop yield using the traditional technologies (Wold Bank 1990; Brune, 1994). However, it should be emphasized that more sustainable yield improvement can be realized where it is possible to develop improved and socially acceptable measures against the major constraints to crop production.

As in all drought-prone areas, the first and foremost environmental constraint limiting crop production in the South Welo zone is the high inter-annual variability in rainfall. Three types of rainfall variability are generally recognized here (a) the rains may start very late; (b) it may end early in the season; and/or (c) there may be extended dry spells between the rains (for similarities with other tropical areas, see Ruthenberg, 1980). In general years of abnormally low annual rainfall have disastrous consequences on the crops. Between 1970 and 1990 alone, Welo had experienced four major drought years that were followed by severe famine (Dessalegn, 1994).

The major soil-related problems currently confronting subsistence agriculture are those related to the physical conditions of the soils --shallow depth, poor drainage, etc., and its chemical conditions --organic matter degradation, nutrient depletion, etc. Among the physical conditions, soil depth is the most crucial as it very much controls the volume of soil that the growing plants exploit for both moisture and nutrients. The soil organic matter is also critical in that it exerts strong control on both the physical and chemical conditions of the soils. Organic matter influences the structure, porosity, moisture retention and infiltration capacity of the soils. It also exerts strong influence on the reserve, supply and storage of nutrients. Accelerated soil and runoff loss are also factors that limit crop production particularly on the slopes.

The other constraint to food production is the low yield potential of the indigenous crops. Rodents, birds and pests also constrain crop production. According to some estimates, farmers lose about 10 to 15 percent of their production due to pests and roddents. The most common pests in some of the *awrajas* are identified as bollworm, armyworm and various stalk borers (Dessalegn, 1991).

INDIGENOUS PRACTICES AGAINST PRODUCTION CONSTRAINTS

Indigenous Strategies Against the Risk of Drought - As elsewhere in the tropics, subsistence farmers in South Welo adopt three major cropping strategies to reduce the risk of drought. First, they tend to plant late, waiting until they make sure the rains are to stay. Second, they cultivate drought resistant but low-yielding crops. Third, they avoid high cost inputs such as fertilizers and high yield varieties (for similarities with other tropical areas, see Ruthenberg, 1980).

Indigenous Crop Management Practices - Peasant farmers in South Welo practice refined systems of seed selection, storage and propagation and cultivate a wide variety of crops. The diversification of crop production is a strategy adopted not only to supply the household requirements but also to spread risk. Almost each one of the crops has cultivars that are adapted to the variable environmental conditions. Farmers keep as many cultivars as possible in store so that they can vary their seeding plans according to changes in the weather (Dessalegn, 1991). They keep fast-growing but low-yielding varieties for the drier years and slow-maturing but low yielding ones for the wetter years. They also vary cultivars depending on the soil conditions (Belay, 1998a). For example, among the local cultivars of sorghum, *mokake*, *rayo*, *jigrite*, *dawe*, etc. are fast-growing but low-yielding varieties cultivated on shallow soils. On the other hand, *jiru* and *tengele* are slow growing but high yielding and hence planted on deeper soils such as the *walka* and *boda*, i.e., soils with high water holding capacities. These adaptations to the wide varieties of environmental conditions are very important to the farmer as they provide him with security against various of environmental hazards.

Indigenous Soil Fertility Management Practices - The traditional fertility management system of Welo employs two strategies to manage the organic matter and chemical fertility of cultivated soils: crop rotation/mixing and organic manuring. Rotational/mixed cropping, in which legumes are integrated, are primarily employed to raise the soil's nitrogen content, while organic manure is added to improve both the physical and chemical fertility of the soils.

The traditional rotational cropping is a system by which fertility restoration is attained by alternating different types of crops on the same cultivated field. The practice is particulatly effective in maintaining the nitrogen status of the soils where leguminous plants are included in the rotation. Legumes are very effective in restoring nitrogen because of the activities of the nitrogen-fixing bacteria (Rhizobium spp.) in their root nodules. Studies conducted in other parts of the world have also established that crop rotation has the added advantage of controlling the spread of weeds. It is also reported that crop rotation disrupts insect cycles and reduce frequency of pest incidence (Karlen and Sharpley, 1994; Forcella and Burnside, 1994).

The practice of crop rotation is not common in the *kolla* zones. Here the most important crop, sorghum, is cultivated mixed with other crops such as sesame, nigger seed, haricot beans and maize. Here mixed cropping is applied to increase the variety and quantity of food produced in the short growing season. The practice allows the fuller use of light, nutrients and water; reduces the incidence of disease and insects; reduces erosion; enables higher returns per hectare; and requires less labor per unit output

(Ruthenberg, 1980). It also allows variety of crops, regenerates soil fertility and reduces the risk of total crop failure. To fit modern management systems, which are normally crop specific, mixed cropping can be easily modified into inter-cropping (i.e., cultivation of two or more crops in proximate but different rows).

Manure is applied as raw-*figh* or composted-*figh*, mostly, on fields close to the homesteads. The primary objective of manuring is to increase the soil organic matter and improve not only the chemical properties (fertility, nutrient storage capacity, etc.) but also the physical conditions (structure, porosity, infiltration capacity etc.) and the water holding capacity. Farmers point out that composted-*figh* is much superior to raw-*figh* and that they apply the latter simply because of the huge labor required to transport the traditional compost to the cultivated fields. It is to be noted that compost has "the property of being able to hold an amount of water equivalent to three times its weight" (James, 1991, p. 130). In fact, farmers argue that uncomposted manure aggravates moisture deficiency in drier seasons, especially on the shallower soils. Farmers point out that once organic manure is applied to a field its residual effect lasts for about five years.

Seasonal fallowing is also frequently practiced in the *dega* and *woina dega* zones to improve both the chemical and physical conditions of the shallow soils. The practice usually involves cultivation of crops such as barley followed by a seasonal fallow. Fallowing not only enables maintenance of humus due to its liberal contribution of organic residues, the slow decay of these materials, and their wide C/N ratios (Brady, 1984) but also stores considerable moisture for the crop that follows.

Indigenous Structural Soil Conservation Practices - Farmers also apply different types soil conservation techniques wherever they perceive the threat of erosion. The indigenous structural soil conservation techniques applied to deliberately control erosion are contour-plowing and *weber*. The structural measures are primarily intended to control runoff and soil loss and thereby improve crop yield. The traditional practice of plowing along the contour produces furrows that to some extent store water until it infiltrates into the soil. However, these simple measures are not effective where rains are intensive and the slopes are long and steep. In many places, contour-plowing is supported by the indigenous structural conservation measure, the *weber*, comprising a series of discontinuous bunds and terraces that develop from narrow strips of land left under grass (Belay, 1998a). Normally, *weber* is a semi-permanent structure and is destroyed when it ages, after establishing a new one a few meters down-slope. Farmers argue that when *weber* ages it grows to a very large size, loses its productivity and stability and the combined effects of these causes a sharp decline in the benefits to the farmers. In very mountainous terrain, where slope is very steep and runoff is extremely heavy, and stones and boulders are abundant, *weber* is replaced by its variant, the *kab* or *kirit*, i.e., traditional stone bunds.

Indigenous agroforestry is also an important component of the traditional farming system particularly in the *kolla* zone. The trees that are commonly integrated in the cropping system are ***Acacia spp.*** (*girar*) and ***Ziziphus spina-christi*** (*kurkura*). Both *ziziphus* and the acacia trees are deep rooted and hence are effective in pumping out nutrients from deep inside the soils. *Ziziphus* is primarily kept and managed in the catchment for its fruit, but also provides firewood, charcoal and fodder (Azene, et al., 1993). The acacia trees provide not only firewood but also encourage the biological fixation of nitrogen and improvement of soil fertility. It should be noted that when trees are integrated within cropping systems they also "...improve the soil's structure and help maintain high infiltration rates and greater water-holding capacity. As a result less runoff is generated and erosion is better controlled" (Morgan, 1996, p. 128). These trees also conserve soil moisture and control erosion with the help of their considerable canopy.

Indigenous Excess Water Management Practices - Where rainfall is heavier, as in the *dega* and *woina dega* zones, cultivation is also supported by an indigenous excess runoff disposal system (i.e. the *boy* system) comprising diversion channels, drainage ditches, and waterways. Diversion channels are constructed up-slope of the cropland to intercept and safely drain runoff that comes from non-arable land. The drainage ditches are shallow (ca. 15 to 25 cm) and narrow (ca. 20 to 30 cm) seasonal furrows that are constructed by simply pressing the plow deep into the soil. They are usually diagonal to the contour (a pattern locally known as *shurube*) although more or less criss-crossing ditches are not uncommon. They are normally constructed about three to five meters apart depending on the slope (for detailed description of drainage ditches see Million, 1996). Runoff from the diversion channels and drainage ditches is collected and safely drained into waterways. Natural channels and human and cattle tracks are utilized as waterways in the traditional system. In some cases the excess water is drained onto grazing land to add to the moisture supply in these areas.

Major Problems of the Indigenous Practices

The main limitations of the indigenous practices arise either from the fact that they are either too limited in their area coverage or intensities of application to significantly contribute to the production improvement. The limited yield potential of the indigenous crop varieties is also another problem of crop production.

Limited yield potential of traditionally cultivated crops - The traditionally cultivated crops in South Welo have very low genetic potential for high yield. Mostly they are taller and/or have larger leaves and do not respond very well to the two elements of agronomic management: dense planting and artificial fertilizers (Wolf, 1987).

Difficulty of extensively applying indigenous soil fertility management practices - It is increasingly becoming difficult for farmers to apply the traditional soil fertility management practices because of the shortage of land. Firstly, expansion of crop cultivation on steep slopes has caused contraction of the grazing land (and livestock population), making it difficult for farmers to obtain sufficient dung for manure. Extensive crop cultivation and the contraction of forests and woodlands have also caused severe shortage of fuel wood forcing farmers to use even the small amount of dung as fuel for domestic use. Secondly, rotational cropping is becoming difficult because of the small sizes of farm holdings. Some of the farmers have to produce enough of the main staple food on the small area of land they own and cannot afford to frequently cultivate the legumes that were traditionally included in the rotation.

Failure of the traditional conservation measures to completely arrest erosion - Firstly, belts of land having very steep slopes and highly vulnerable to erosion are created when the traditional conservation structure, the *weber*, is destroyed and cultivated. Secondly, the practice of destroying *weber* encourages net down-slope movement of soils. When a *weber* is destroyed the soil is spread down-slope and this ultimately leads to net down-slope movement of large amounts of soils and severe degradation of slopes. Thirdly, *weber* is applied only where farmers perceive erosion as a threat (i.e. where rilling and gullying is common), and normally the imperceptible sheet-wash escapes the attention of the farmers. Fourthly, the inter-*weber* spacings are too wide and graded for the respective slope gradients to effectively arrest soil erosion.

THE EXTENSION APPROACH AGAINST PRODUCTION CONSTRAINTS

The Modern Strategy

To overcome the constraints to crop production and improve yield in Ethiopia and the South Welo zone, the 'National Extension Intervention Program' (which became operational since 1995) recommends extensive use of:

- improved seeds to raise the yield potential of crops; however, improved varieties are available only for a few crops --maize, sorghum, teff and wheat;
- chemical fertilizers (DAP and Urea), pesticides, and herbicides to create a conducive environment for the healthy growth and development of crops;
- extension advice and farm credits. The extension program provides model farmers a 25% down-payment credit to cover the cost of improved seeds and fertilizers along with technical assistance (Habtemariam, 1996)

The cost of the recommended extension package is estimated at about 500-800 Birr per hectare depending on the crop (Takele, 1996). However, such a costly package may not be sustainable when applied in the climatically marginal and drought-prone areas such as South Welo because of its multifaceted limitations.

Major Problems of the Modern Technologies

The major problem of the extension package is its dependence on high cost external inputs in an environment where the risk of drought is very high (the per hectare cost of the input is too high to be readily adopted by peasant farmers that mostly live below the poverty line). Farmers clearly point out that shortage of rainfall increases the risk of total loss of investment on the modern inputs. The environmental and health hazards that may result from extensive use of chemicals in the long term is also a problem to reckon with.

Another problem arises from the fact that the extension program completely undermines the critical role organic matter, depth, and drainage of soils play in the response of crops to modern inputs. The extension program assumes that productivity can be increased many-fold only through intensive use of chemical fertilizers, herbicides and insecticides. However, researchers have repeatedly noted the fact that productivity improvement cannot be attained where the soil is poorly drained, very shallow, depleted of its organic matter, and exposed to accelerated erosion (Mulat, 1996; Sahlemedhin, et. al., 1993). The typical features of a large proportion of the cultivated soils of Welo in particular, and the Northern highlands in general, is their shallow depth, very low organic matter, and poor moisture holding capacity. The shallow depth and low organic matter content increase vulnerability to drought by reducing the soil's moisture holding capacity. The footslopes mostly covered by Vertisols are also vulnerable to water-logging when there is too much rain, particularly where the rain is high and evapo-transpiration low as in the *dega* and *woina dega* zones.

Use of the modern package is also constrained by lack of reliable market. For instance, as frequently observed in most of Sub-Saharan Africa, a favorable weather and subsequent higher crop yield by all the farmers in an area usually results in a sharp drop in the prices of harvested products. For instance, reports indicate that the good harvest of maize and wheat in 1995/96 led to a sharp decline in prices, particularly, in the surplus producing regions of Ethiopia (Mulat, 1996). The attempt on the part of the government to stabilize prices was also not effective because of lack of sufficient funds to purchase the surplus. Under this condition, farmers find it very difficult to predict the economic benefits they may gain from their investment in the inputs.

The other problem of the extension package is its dependence on a narrower genetic base when compared to the traditional systems. The improved varieties have very low resistance to drought, pests and disease causing organisms, making the farming community more vulnerable to the hazards of environmental stress. The dependence on only a few improved crop varieties --wheat, maize, sorghum and *teff*, may bring about not only loss of insurance the diversity of the traditional crops provide against the very common environmental hazards but also the disappearance of the varieties of crops and their cultivars (loss of bio-diversity). These improved seed varieties also lose their viability and abandoned by farmers in a matter of a few years because of disease and other problems (Fassil, 1993; Tennassie, 1985; Betru, 1983). For example, about 9 wheat varieties released for use by peasants in Arsi, in the late 1960s and early 1970s, had to be abandoned because of stripe rust, stem rust and leaf blotch. Similarly, of the 7 varieties of barley released between 1970 and 1979, only one was adopted because of similar problems. Moreover, improved varieties of crops such as sorghum are not only susceptible to bird attack but also have stalks that are too short to yield the biomass required for fuel or fodder (Mulat, 1996). It should also be noted that the country has not reached a stage where organized supply of improved varieties of crops are attained and this strongly limits the sustainability of the extension program.

The other limitation of the extension package is that it ignores the linkage and complementarity of crop cultivation and livestock production systems. Livestock is traditionally kept to provide not only food but also to support crop cultivation by supplying draught power, pack animals and manure. These animals also provide security against crop failure as they are easily converted to cash when there is an emergency situation. Cultivated fields are also important sources of fodder for the livestock. In fact, according to some estimates about 60 percent of the feed during the dry seasons comes from the cultivated fields mainly in the form of cereal straws (Department of Planning, 1993). Thus, it is necessary to have rehabilitation and improvement of grazing lands so that crop farming does not lose its healthy linkage with the livestock sector.

THE NEED FOR INTEGRATION

As noted in the discussion above, both the indigenous practices and the modern techniques have serious limitations and none of them alone can effectively overcome the constraints to crop production. But they have also features that can be combined and developed into a more sustainable agricultural management package. The farmer benefits much more than he would from either of them if he were to combine the strong features of both. Thus, there is an urgent need for integration of indigenous practices with the modern extension package to develop more effective and sustainable management systems. Practices such as manuring, mixed cropping, crop rotation, and soil conservation should be refined and integrated with the modern technologies such as artificial fertilizers. Manure increases the soil organic matter and improves not only the chemical fertility but also moisture storing capacity of the soil. Upon decomposition, soil organic matter releases important micro-nutrients that are normally missing in the artificial fertilizers recommended by the extension programs. Improvement of moisture capacity is particularly of great significance to crop production in the drought-prone areas such as South Welo because it reduces the vulnerability of crops to rainfall variation.

When manure is combined with artificial fertilizers it considerably increases the efficiency of the new technology. Moreover, where manure is added, smaller amounts of artificial fertilizers are required to raise yield and this effectively reduces the cost of the extension package. A trial conducted in Burkina Faso illustrates very well the complementary effect of organic matter and artificial fertilizers -- the three organic practices increased the efficiency of nitrogen application by 20 to 30 percent (Table 5).

Mixed cropping increases the total output per unit area of land and at the same time reduces the damage that may result from disease and pests. The denser growth also suppresses weeds. Mixed cropping also not only allows varied food supply but also reduces the vulnerability to environmental stress and the risks of complete crop failure. Where necessary mixed cropping can be improved to inter-cropping (i.e., growth of two or more crops in proximate but different rows) so that farmer can attain most of their objectives but at the same time allow more effective use of fertilizers and other modern techniques. Ruthenberg (1986) citing McIntosh (1975) points out that in some Asian countries (eg. Java) mixed cropping has been effectively replaced by inter-cropping so that there is better spacing of plants and each row of plant can be individually weeded, manured and fertilized. The indigenous conservation practices can be improved and integrated with the modern techniques on cultivated slopes not only to control erosion but also to minimize seed and fertilizer loss.

Table 5. Complementary effects of artificial and organic fertilizers on sorghum yield in Burkina Faso

Treatment	Sorghum yield (tons/ha)	
	Without artificial fertilizers	With artificial fertilizers[1]
No organic treatment	1.8	2.8
Sorghum straw[2]	1.6	3.4
Manure[2]	2.4	3.6
Compost[2]	2.5	3.7

[1] At 60 kg on N/ha; [2] All organic materials at rates of 10 tons/ha

Source: Wolf (1987)

Table 6. Maize and Sorghum yields inside and outside the crown overhang of Acacia albida in the Hararghe highlands of Ethiopia

Type of crop	Grain yield (kg/ha)	
	Outside the crown Overhang	Inside the crown overhang
Maize	1920 (100)	3390 (177)
Sorghum	1570 (100)	2130 (136)

Source: Poschen (1986) cited in Müller-Sämann, and Kotschi (1994)

The traditional agroforestry practices in the *kolla* zones also improve the fertility and physical conditions of the soils, and make food production more sustainable. For example, the leaves of the acacia trees which normally fall at the beginning of the rainy season, supply the soil with large amounts of nutrients and organic matter. Grain yields under the crown overhangs of acacia trees are much higher than those in the open field (Table 6). A stand of 50 to 60 acacia trees per hectare is reported to increase yields by 50-100 percent. Several factors explain these higher yields; "soil organic matter, pH value, microbiological activity and cation exchange capacity, as well as supply of macro-nutrients, were markedly higher under Acacia albida than on open land." (Müller-Sämann and Kotschi, 1994, p. 151)

CONCLUSION

Sustainable improvement of food production in the drought-prone areas of Ethiopia cannot be attained following the current extension approaches as it is not appropriate to the climate, the soil conditions, and the circumstances of the farmers. Firstly, although the improved seeds have the genetic potential for high yields they have very little capacity to withstand the frequent environmental stress, such as drought, waterlogging, pests and disease-causing organisms. They are also not very well adapted to the shallow and degraded soils. Secondly, although artificial fertilizers are very effective in selectively mitigating deficiencies of nitrogen and phosphorus, they contribute little towards the improvement of the organic matter which plays a critical role in the improvement of the physical conditions and moisture retention capacities of the soils. Thirdly, the erratic rainfall in the Welo highlands makes investment in artificial fertilizers very risky because both too-wet and too-dry conditions may cause sharp declines in yield or even total crop failure. Fourthly, as frequently observed in most of Sub-Saharan Africa and other parts of Ethiopia, favorable weather, and subsequent improvements in yields by all the farmers in an area, usually result in a sharp drop in the price of harvested products. As a result, farmers may fail to benefit from the increased yield because of lack of sufficient market.

To be more effective and sustainable in the drought-prone areas of Ethiopia in general, and in the South Welo zone in particular, agricultural management packages should be low-cost and adaptable to the erratic rainfall, the degraded soils, and the circumstances of peasant farmers. A package that can fulfill these requirements can be designed by improving and integrating the indigenous agricultural practices with the modern package through adaptive technology development programs. The indigenous component increases the social acceptability of the package as it conforms to the high labor and low capital demands of the subsistence agriculture, the survival and risk avoidance strategies of the peasant farmers, and the cultural and social institutions of the community (DeWalt, 1994). Such integration should be carried out in such a way that technological development leads to the empowerment of the farmers by increasing the local input particularly the knowledge and skills of the farmers. A management package developed in this way will not only have faster and more widespread acceptance but also attract strong farmers' participation because it creates a sense of peasant ownership and authorship of the management systems (White and Jickling, 1995). It should be noted that the "main purpose of development is to inspire, mobilize and engage the initiatives and resources of the poor for productive efforts" (UNDP, 1991; Brune, 1994).

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