AFRICA'S POTENTIAL FOR THE ECOLOGICAL INTENSIFICATION OF AGRICULTURE

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INTRODUCTION

The present ability or otherwise of Africa to cope with climate change and improve its agricultural production depends on the environment and natural resources base of the continent, on the impacts of its past and on the nature of its present interactions with the outside world. Africa is a large continent exceeded in land area only by the whole of Asia. In spite of its size, Africa is the least populated of the continents. The human population, which was estimated at nearly 800 million in 2000 (UNEP, 2006), is much smaller than that of India. Africa is usually referred to as dry because the biggest dry land in the world, The Sahara, is in it. The deserts of Africa add up to 1 274 million hectares out of a total land area of more than 3 025 million hectares (UNEP, 2006). But the tropical rainforest area of Africa alone, which receives rain virtually the whole year round, is bigger than India. Therefore, it is not aridity *per se* that prevents Africa from increasing its agricultural productivity and being able to feed all of its people and more.

Africa is the continent that has been the most devastated by slavery, e.g. as recounted by Gray (1961) for Southern Sudan, and colonialism, as recounted by Robinson and Galagher (1965) for the whole continent. And the extraction of able people, both skilled and unskilled, still continues under various forms such as brain drains and economic refugees. No society debilitated thus can be expected to retain its capacity to develop its essential infrastructure, especially for research and development, and build self-sufficiency in agricultural production.

Africa is the most endowed of continents in mineral resources and is rich even in petroleum, though not as rich as the Middle East. These minerals attract much external interference, for example in the eastern Congo (Wikipedia, 2010a). This phenomenon of external perturbation resulting in internal instability is not restricted to the Congo. It is widespread in Africa. Diamonds are among the other minerals that are used to finance conflicts (Wikipedia, 2010b), despite repeated international efforts to control and regulate their trading so that the legitimate governments where these resources are found can use the revenue for the development of their

countries. Africa is also well endowed in potential for alternative renewable energy from hydro, geothermal, solar and wind resources.

Therefore, if the mighty outside world would stay outside and allow perturbed Africa to settle down, or, better still, if it would make up for its past perturbing by supporting attempts at stabilization rather than continue to interfere for gain, Africa could develop its agriculture according to its own interests and would be able to feed itself and produce surplus to help feed other parts of the planet.

AGRICULTURAL AND NATURAL BIODIVERSITY IN AFRICA

Africa is often viewed as having a relatively homogenous environment because of the broad vegetation belts – desert, savannah and forest – that stretch from the Atlantic coast on the west to the Red Sea and Indian Ocean coast on the east. This superficial uniformity actually encompasses vegetation types that are complex and rich in biodiversity, comprising a greater diversity of ecosystems than for any other equivalent area of land in the world (White, 1983). White referred to these ecosystem complexes as regional centres of endemism, regional mosaics and regional transition zones (see Figure 1).

Similarly, it has often been assumed that Africa's agriculture was relatively homogenous, and there has been frustration at the lack of improvements in agricultural production from the Green Revolution approach based on the package of 'improved seed' selected to suit a homogenous environment, supported by agrochemicals in the form of fertilizers and pesticides, usually applied under irrigation. For food crops, the focus has been on mainly maize, rice and bread wheat (IAC, 2004). These efforts have ignored sorghum, Africa's most diverse and widely adapted cereal, which has the best ability of all its cereals to provide farmers with genetic resources to mitigate and adapt to climate change (van Oosterhout, 1993), as well as pearl and finger millets and many other crops.

The reality is that diversity is the norm in African farming systems with a farmer typically growing ten or more species and varieties of crops (IAC, 2004) in their

home gardens and fields. The traditional farming systems of Ethiopia, for example, use over 100 different crop species (Edwards, 1991). Lack of appreciation of the diversity in both genetic resources and its accompanying traditional knowledge as well as lack of investment in infrastructure and appropriate research and development (R&D) are the main reasons why Africa's agriculture has not developed sufficiently. Other reasons, particularly the ignoring of the role of Africa's women farmers, are well discussed in the Sub-Saharan Africa Report of the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD, 2009).

Dixon *et al.* (2001) carried out a global assessment of farming systems in which they recognized 18 distinct systems in Africa, as shown in Figure 2. The information on these farming systems is summarized in Table 1. The criteria used to differentiate the systems were a) the natural resource base; b) the principal crops and domestic animals; c) the level of crop-livestock interaction; and d) the scale of operations. The agricultural systems are arranged in a descending order of the percentage of the population that they support.

In a study for the International Federation of Organic Agriculture Movements (IFOAM) (Edwards, 2004), the authors found that there was a strong coincidence in the distribution of Africa's floristic regions as identified by White (1983), shown in Figure 1, and the farming systems identified and mapped by Dixon *et al.* (2001), shown in Figure 2.

Four farming systems – maize mixed, cereal/root crop mixed, root crop and agropastoral millet/sorghum – provide the livelihoods for half of the population and occupy 42 percent of the land area in Sub-Saharan Africa. These systems are dominated by smallholder farmers producing and marketing their produce locally. Even within one country, produce rarely moves much outside the agro-ecological zone in which it is grown. One of the biggest challenges for organic producers in Africa who wish to export their products is the lack of infrastructure to get their produce transported and lack of contacts in the importing countries (Taylor, 2010). The situation in North Africa is different because of the easy access to Europe. But

TABLE 1

Farming systems of the African Region with their percentage land area and population, based on Dixon et al. (2001)

FARMING SYSTEM	AGRICULTURAL POPULATION %	LAND AREA %	MAP KEY NUMBER	PRINCIPLE FOOD CROPS AND DOMESTIC ANIMALS
In Sub-Saharan Africa				
1. Maize mixed	15	10	9	Maize, legumes, vegetables, tobacco, cotton, cattle, shoats, chicken
2. Cereal/root crop mixed	15	13	8	Maize, sorghum, various millets, cassava, yams, legumes, vegetables, cattle, chicken
3. Root crop	11	11	7	Yams, cassava, legumes, vegetables, pigs, chicken
4. Agropastoral millet/ sorghum	9	8	11	Sorghum, pearl millet, legumes, sesame, cattle, shoats, chicken
5. Highland perennial	8	1	5	Banana, plantain, enset, coffee, cassava, sweet potato, taro, legumes, cereals, cattle, shoats, chicken, honey bees
6. Pastoral	7	14	12	Cattle, camels, shoats
7. Forest-based	7	11	3	Cassava, maize, legumes, taro, wild fruits and vegetables, cattle, pigs, chicken
8. Highland temperate mixed	7	2	6	Wheat, barley, sorghum, millets (including teff), legumes, oil crops, potato, cattle, shoats, chicken, honey bees
9. Tree crop	6	3	2	Cocoa, coffee, oil palm, rubber, yams, maize, chicken
10. Commercial agriculture small and large holders	5	4	10	Maize, pulses, sunflower, cattle, shoats, chicken, game animals
11. (Coastal) artisanal fishing	2	3	14	(Marine) fish, coconut, cashew nut, banana, yams, fruits, goats, chicken
12. Irrigated (mostly large scale)	2	1	1	Rice, cotton, perennial fruits, vegetables, rainfed crops, cattle
13. Rice/ tree crops	2	1	4	Rice, banana, coffee, maize, cassava, legumes, livestock
14. Sparse (arid) agriculture	1	18	13	Irrigated maize, vegetables, date palm, cattle, shoats, chicken
15. Urban-based	3	<1	Not shown	Fruits, vegetables, dairy cattle, shoats, chicken
In North Africa				
16. Highland mixed	30	7	2	Cereals, legumes, sheep
17. Rainfed mixed	18	2	3	Tree crops, cereals, legumes
12. Irrigated	17	2	1	Fruits, vegetables, cash crops
18. Dryland mixed	14	4	4	Cereals, sheep
6. Pastoral	9	23	5	Shoats, barley
15. Urban-based	6	<1	Not shown	Horticulture, chicken
14. Sparse (arid)	5	62	6	Camels, sheep
11. Coastal artisanal fishing	1	1	Not shown	Fish

'Shoats' = mixed flocks of sheep and goats

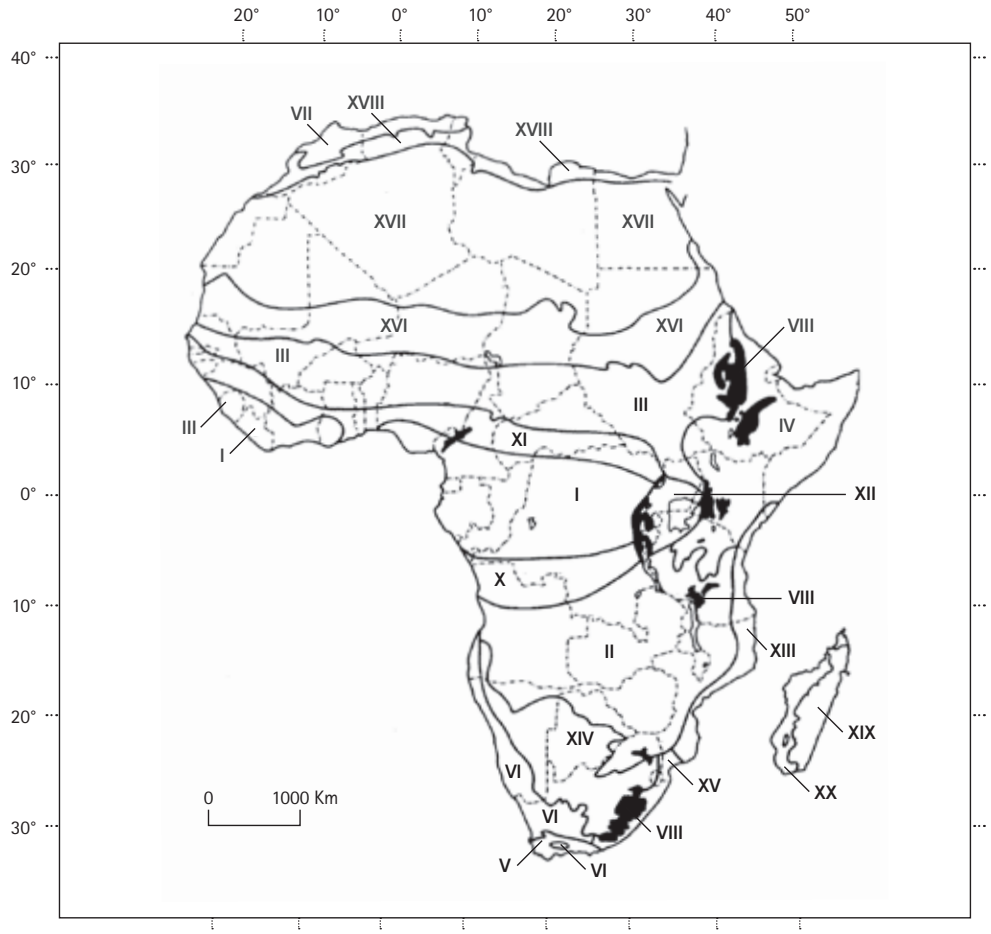
this agriculture is also dominated by smallholders with nearly half the population concentrated in less than ten percent of the land in the northwest edge of the continent, and along the Nile River in Egypt.

Nearly all the farming systems are mixed, i.e. the farmers keep livestock as well as produce crops. This is because the livestock provide many services, not just meat and milk, for their owners. Without livestock, the essential recycling of nutrients from crop residues and natural vegetation back into the crop land would not take place. This is particularly important for all areas which have marked dry and moist seasons with the farmers dependent on rainfall for their crop production. During the dry season, ruminants break down the plant materials they feed on into manure. This is one of the most important constituents of good quality compost. Until the introduction of chemical fertilizers, the fertility of all types of crop land was maintained through the recycling of animal wastes back to the soil. The majority of Africa's smallholder farmers are still maintaining their animals to help in this recycling of nutrients. If they are properly herded, the other function that domestic animals provide is the maintenance of the vegetation balance in ecosystems. Their hooves can break the crust of dry soil so that rain water can penetrate. They also trample down non-palatable vegetation so that it can break down and get incorporated into the soil, providing good soil structure. Their trampling can also break open the soil so that seeds in the soil seed bank can germinate and the biodiversity in the ecosystem can be maintained (Adams and Butterfield, 2006). These functions of domestic animals are very well understood by pastoralists and agro-pastoralists, as well as to a lesser extent by settled smallholder farmers.

In Sub-Saharan Africa, commercial farming, mostly in Southern Africa, combined with irrigated production in the Niger River basin and along the Nile and its tributaries in the Sudan, engages only seven percent of the population and occupies only five percent of the land. The commercial and irrigated areas are dominated by cash crops and have had, therefore, some investments in infrastructure – dams, irrigation systems, roads and markets – in order to bring the products to national and global markets.

FIGURE 1

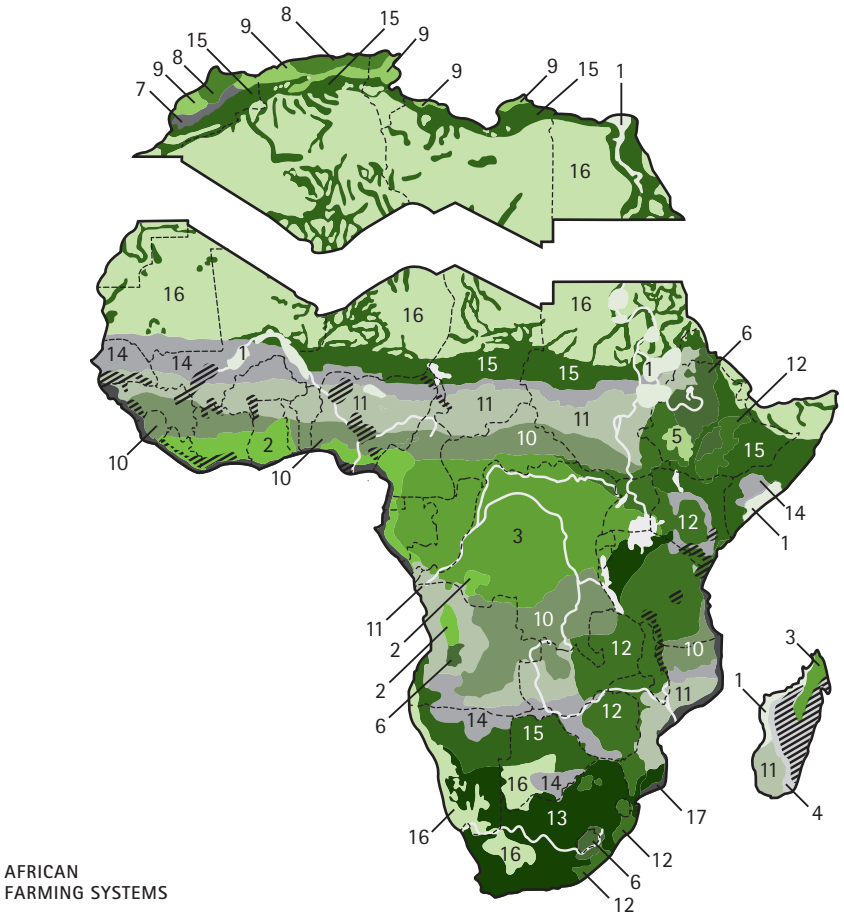
The main floristic regions of Africa and Madagascar, from White (1983)

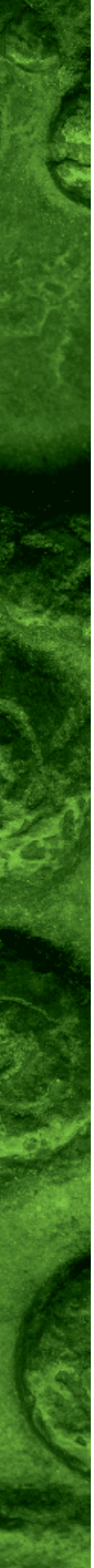


I Guinea-Congolian regional centre of endemism
II Zambezian regional centre of endemism
III Sudanian regional centre of endemism
IV Somalia-Masai regional centre of endemism
V Cape regional centre of endemism
VI Karoo-Namib regional centre of endemism
VII Mediterranean regional centre of endemism
VIII Afromontane archipelago-like regional centre of endemism, including
IX Afro-alpine archipelago-like region of extreme floristic impoverishment, where the land goes over 3 000 m
X Guinea-Congolian/Zambezian regional transition zone
XI Guinea-Congolian/ Sudanian regional transition zone
XII Lake Victoria regional mosaic
XIII Zanzibar-Inhambane regional mosaic
XIV Kalahari-Highveld regional transition zone
XV Tongaland-Pondoland regional mosaic
XVI Sahel regional transition zone
XVII Sahara regional transition zone
XVIII Mediterranean/ Sahara regional transition zone
XIX East Malagasy regional centre of endemism
XX West Malagasy regional centre of endemism

FIGURE 2

African farming systems, according to Dixon et al. *(2001)*





Overall, however, it is obvious that African smallholder agriculture has not attracted the level of investment needed to raise its productivity through homogenizing and industrializing it, as has been done for industrial agriculture in other continents. Can Africa afford to follow the agricultural development path for industrial agriculture to meet its food requirements? The IAC report (2004), "Realizing the promise and potential of African Agriculture", commissioned by then United Nations Secretary General, Kofi Annan, clearly shows that a very different approach must be used. This position is now also confirmed by the IAASTD (2009).

Kimbrell (2002), in his book "Fatal harvest: The tragedy of industrial agriculture", describes in pictures and text the destructive impacts to the land and farmers of the industrial agriculture model developed by the United States of America, and how these farmers have become more and more dependent on costly solutions. The solutions are costly both in terms of health of the environment and the economy of the farm, as well as the non-renewable resources and personnel needed to run it. The agrochemicals industry, the machinery and mechanics, the highly technical advisors using Geographic Information Systems (GIS) and other data to advise farmers, as well as the immigrant workers needed to provide the labour, make the expenses rise and undermine local food security. Kimbrell also describes and shows the improvements to the environment and human health, including that of the farmers, of growing food organically.

IFOAM issued a press release in February 2010 stating that certified organic produce is now being grown on 35 million hectares of land operated by 1.4 million producers, most of them smallholder farmers (IFOAM, 2010). Although the greatest area of land certified as growing products organically is in Australia, the largest number of certified organic farmers is in Africa.

It is true that when it comes to bulk supply for a population that is largely urbanized and homogenized in its food culture, industrial agriculture has been able to provide the products needed. It has also produced the food for shipments of food aid to people in Africa after they have suffered from drought and conflicts. But this is only because the whole of the industrially managed food chain, from

seed through the farm to the market, is heavily subsidized. Without these subsidies, food aid would be unaffordable for developed countries to send to the developing countries, and Africa would be able to develop its own internal markets to provide food from within the continent for its own people, as Zambia was able to do in the food crisis of 2002 when it refused aid food contaminated with genetically modified seed, and opted to buy the food it needed from elsewhere. At the time of the refusal in October 2002, there were over a million metric tonnes of maize available in neighbouring African countries (FAO, 2003). The development of good internal and regional markets in Africa would make it attractive to develop permanent improvements to the infrastructure needed to improve agricultural productivity and transport as well as enhance local R&D to sustain it all. This would greatly benefit the development and expansion of ecological/organic agriculture for both local markets and export.

AFRICA'S CENTRES OF ENDEMISM AND THEIR AGRICULTURE

Most of what is known of global biodiversity is summarized as the number of described species. The Global Biodiversity Assessment of the United Nations Environment Programme (UNEP) used a working figure of 1.75 million described species for the world, which were considered to be only 13 per cent of the 13.6 million species estimated to exist (Heywood and Watson, 1995). The greatest number of species already known is found in tropical rainforests on land and in coral reefs in the sea. The total number of species in a given area generally decreases with its distance from the equator, both north and south, and with increasing altitude. However, the proportion of the known biodiversity is in reverse relationship to its richness with the best known biota being in the temperate and economically developed parts of the world. This state of knowledge for natural biodiversity is equally true for agricultural biodiversity, with the highest number of 'orphan' crops ignored by mainstream research also being found in the tropics and other economically less developed parts of the world (Rehm and Espig, 1991).

For Africa, the flora of higher plants is relatively well known compared to other continents in the tropics (WCMC, 1992; White, 1983). Birds are the best studied and documented group of animals with many identification guides available, for example Sinclair and Ryan (2003) and for invertebrates, butterflies have also been relatively well documented (e.g. Carcasson, 1981). Kingdon has produced a comprehensive compilation of the mammals, published in several parts and summarized in his "Field Guide to African Mammals" (Kingdon, 1997). However, for all other groups of organisms, even the little that is known has only infrequently been compiled and made available.

In identifying the natural biodiversity regions in Africa, Kingdon (1989) uses the fact that around one quarter of the known plants and animals indigenous to Africa are clustered in distinct geographical enclaves referred to as regional centres of endemism. In this, he follows and enriches the work of White (1983). There is a broad correspondence between the distribution of the farming systems and floristic regions in Africa. Therefore, by identifying the farming systems associated with the floristic regions, it is possible to set broad priorities for agricultural intensification based on the organic principles of health, ecology, fairness and caring for the earth. Such intensification could result in improved production for the farmers without extending crop production further into the natural vegetation, and this would benefit the biodiversity of both the farmed and the non-farmed areas.

Following are brief descriptions of the farming systems found in the 11 major African floristic regional centres of endemism and one regional mosaic. The transition zones recognized by White (1983) have not been described though they are shown in Figure 1. This is simply because, as transition zones, their farming systems are mixtures of those of the centres of endemism which are adjacent to them.

Guinea-Congolian regional centre of endemism

This regional centre (I in Figure 1) includes the Congo River basin, which Kingdon (1989) describes as the "huge green belly" of the continent, and the Guinea Forests of West Africa. These are the hottest and wettest parts of the continent.

The natural vegetation inside the Congo River basin is tropical rainforest with swamp forests and edaphic grasslands occurring in areas of impeded drainage. According to White (1983), Fabaceae (Leguminosae) is the family that is the richest in species in this region. The potential for high quality animal feed and for nitrogen rich compost making is thus high.

The main staple crops grown by smallholder farmers are cassava, maize, beans and taro. The people also make much use of wild fruits and vegetables as well as of non-timber forest products, for example honey and caterpillars. The importance of such products to the local economy and to the conservation and sustainable use of forests is now receiving more attention (Crafter *et al.* 1997). Fish are important in the local economy. The number of fish species in the Congo River is more than 400 belonging to 24 families (Lowe-McConnel, 1969). Development of artisanal and improved local fishing along the rivers should learn from the disasters of other areas, notably Lake Victoria, and avoid the introduction of alien species, such as the Nile Perch.

The agriculture of the wet Guinea Forests of West Africa is now dominated by tree crops i.e. cocoa, coffee, oil palm, rubber, though yams and maize are also important (Dixon *et al.*, 2001). Since the mid-1990s, the returns from the four main tree crops, but particularly from coffee and cocoa, have dropped dramatically, and many farmers have become impoverished (Khor, 2010). An ecological/organic approach to intensification and diversification, particularly that which encourages mixed planting of perennial crops for trade with annual crops for local food security, and the use of indigenous legumes for green manure and mulch could help restore the fertility of the land and build resilience for coping with climate change. Where it is being implemented, fair trade combined with organic certification for the marketing of the organic products can bring significantly better returns to the local farmers than normal trade (AdeOluwa, 2010).

Zambezian regional centre of endemism

Much of the Zambezian regional centre (II in Figure 1) is over 900 metres above sea level with rainfall over 1 400 mm in the northern parts, but this decreases to the south and west. The characteristic soils are leached and acidic, often shallow and stony with a hard pan restricting rooting. White (1983) identified over half of the plant species occurring in this region as endemic. The most widespread and characteristic vegetation type of the Zambezian regional centre of endemism is woodland. Tree branches are regularly lopped and burnt to improve the fertility of the soil, a system called "citimene". This has had a marked impact on the dynamics of the vegetation with the trees being more or less uniform in appearance.

Four agricultural systems are found in this regional centre of endemism: root crops and highland perennial crops in the wetter areas to the north, and mixed maize and other cereals and root crops in the drier south and west respectively. Low soil fertility is a major constraint to raising crop production. The promotion of animal production through a holistic management of communal herds (Adams and Butterfield, 2006) and composting would rehabilitate the environment, as well as improve soil fertility and human nutrition.

Sudanian regional centre of endemism

The Sudanian regional centre of endemism (III in Figure 1) forms a belt from the west coast in Guinea to the Red Sea coast in Sudan and Eritrea. The belt widens across the middle and reaches into northern Uganda, and occupies most of Southern Sudan as well as the western lowlands of Ethiopia. The land lies mostly between 500 and 700 metres above sea level. The rain falls between May/June and September giving around 1 000 mm per annum in the south, where there is woodland, to about 600 mm per annum in the grasslands of the north. This area also includes important wetlands: the diminishing Lake Chad, the Niger River delta in the west, and the Sudd and White Nile in the east. Fires are a regular feature of the slash

and burn type of agriculture that takes place because the tall grasses become silicified and inedible for animals. The fires clear the way for new plant growth for both domestic and wild animals.

The biodiversity includes several trees of economic importance, e.g. *Acacia senegal*, which produces gum arabic, *Balanites aegyptiaca* (the desert date), which has edible fruits and produces an edible oil, and the endemic *Butyrospermum paradoxum*, the shea butter tree.

Cereal/root crop mixed farming is the dominant agricultural system of this region. It is considered that sorghum (*Sorghum bicolour*) cultivation evolved in this region, along with cowpea (*Vigna unguiculata*), sesame (*Sesamamum indicum*), watermelon (*Citrullus lanatus*) and roselle (*Hibiscus sabdariffa*) (Harlan *et al*, 1976). Pastoralism is also important, but greater attention could be given to improving productivity along with environmental rehabilitation. With mixed farming and composting, agricultural productivity can easily be raised.

Somalia-Masai regional centre of endemism

The Somalia-Masai regional centre of endemism (IV in Figure 1) is dry, with rainfall rarely exceeding 500 mm a year. Over half of the 2 500 plant species found are endemic to this regional centre of endemism. Most of the vegetation is deciduous bushland and thickets that give way to semi-evergreen and evergreen bushland on the lower slopes of mountains. Seasonally waterlogged areas become grasslands. This floristic region is the source of incense and myrrh, which are gums collected from species of *Boswellia* and *Commiphora* respectively. Other species with high traditional and potential wider economic value include the Yehib nut, *Cordeauxia edulis*.

Agropastoralism and pastoralism have been practiced throughout this floristic region for a very long time, probably as long as cultivated agriculture in the Ethiopian highlands, i.e. for at least 5 000 years. The people, the vegetation and the wildlife are hardy and have co-evolved to cope with a very harsh and variable climate. This has been well documented for Masai pastoralism (FAO, 2003).

Traditional crop cultivation is important along the edges of rivers. This can be expanded through water harvesting and irrigation using ground water. The existing animal production would make it easy to make compost of high quality and maintain high productivity in the irrigated agricultural areas.

Cape regional centre of endemism

The Cape region (V in Figure 1) is floristically the richest part of Africa. There are over 7 000 species in this very small area, of which more than half are endemic (White, 1983). The plants are adapted to cool moist winters contrasting with hot and dry summers with frequent fast and fierce summer fires. Many of the species in this centre of endemism have been taken into cultivation and developed into important horticultural plants, for example, the Proteas, Heaths and Heathers, as well as many bulbous plants. Rooibos and honeybush tea have been developed from local species and now have an international market as speciality teas, including with organic certification. Modern commercial agriculture based on crops from the Mediterranean region, particularly grapes, has expanded into this area. A shift to composting for maintaining high soil fertility would be easy because animal production is already important, though it could be expanded to all farms.

Karoo-Namib regional centre of endemism

The Karoo-Namib regional centre of endemism (VI in Figure 1) is a strip of arid land stretching from the Cape for 2 000 kilometres up the western Atlantic Ocean coast through Namibia to Angola, and stretching inland to the Orange River. Half of the 4 000 species of plants found in the area are endemic to it. All the species are adapted to withstanding long periods of drought and, when moisture comes, to responding very fast in growth and flowering. Many of the annuals are grown as horticultural varieties to decorate public parks and gardens because of their very hardy nature.

The dryness mostly restricts agriculture to transhumant pastoralism and to extensive ranches of low carrying capacity. However, even in this region, there is some crop cultivation, especially where some supplementary irrigation is possible.

Mediterranean regional centre of endemism

This area (VII in Figure 1) is dominated by the Atlas Mountains and is found at the north-western edge of the continent. Around 4 000 species occur in this area, but only 20 percent of them are endemic to North Africa.

There are three agricultural systems found in the Atlas Mountains and along the area between the mountains and the Mediterranean Sea. These are the highland mixed, rainfed mixed, and dryland mixed farming systems. Over 60 percent of the agricultural population obtain their livelihoods from these three systems. Since the farming systems are already mixed and there is a large agricultural labour force, i.e. producing crops and animals, high quality composting for intensive ecological crop and animal production can be easily introduced throughout.

Afromontane archipelago-like regional centre of endemism

The Afromontane region (VIII in Figure 1) is scattered on the mountains and highlands which are found in every country in Eastern and Central Africa, as well as in Cameroon in West Africa and the mountains in Southeast Africa between the Republic of South Africa and Mozambique. All these highland areas are generally wetter than the surrounding lowlands, and are thus important water towers for these areas.

Taken as a whole, the Afromontane floristic region has about 4 000 species of which about 75 percent are endemic (White, 1983) with about one-fifth of the genera also being endemic. The vegetation is forest and woodland adapted to alternating dry and wet periods on the sloping areas up to around 3 000 metres above sea level with edaphic grasslands and wetlands on the flatter areas.

The main agricultural types in this regional centre of endemism are highland perennial and highland temperate mixed farming systems. Both systems combine animal husbandry with crop cultivation and grow a wide range of crop species and varieties within the species. The greatest agricultural biodiversity is found in Ethiopia, which has been recognized as one of the world's Vavilov centres for crop genetic diversity. There is little flat land in the Afromontane region. Therefore, soil and water conservation are critical for the survival of the farmers, and many ingenious indigenous systems have been developed (Reij *et al.*, 1996). Since the farming systems are mixed, high quality compost can easily be made by the farmers, as has already been shown in Ethiopia (Edwards *et al.*, 2007).

Afro-alpine archipelago-like regional centre of endemism

White (1983) refers to the Afro-alpine areas of Africa (IX, not shown separately in Figure 1) as "a region of extreme floristic impoverishment". In the sense that the species numbers in the flora are low, he is right. But Hedberg (1969) has shown that 80 percent of the plant species in the Eastern Afro-alpine region are endemic to that region.

The environment is subjected to extremes of temperature every day. It freezes at night, and day temperatures become hot, especially when the skies are clear. The plants are thus rooted in cold soil, but their aerial parts can have high temperatures. This condition gives rise to a range of adaptations, e.g. cushion forms, acaulescence, succulence, and plants which close up tightly at night and open up during the day. Plant growth is slow. Therefore, though the environment is wet the whole year round, the vegetation is vulnerable because it cannot recover quickly after it has been disturbed, let alone destroyed.

The Afro-alpine areas are important as water towers for their surrounding lowers areas. In Ethiopia, people live in these areas cultivating barley and grazing their sheep and cattle. In many other parts of Africa, for example on Mounts Kenya and Kilimanjaro, the most important economic activity is tourism.

Zanzibar–Inhambane regional mosaic

This area (XIII in Figure 1) has been known as the spice coast for more than 2 000 years. It includes the islands of Zanzibar and Pemba. The distinctive vegetation occupies a narrow strip along the Indian Ocean coast starting from the southern tip of Somalia and continuing south into Mozambique. Due to the influence of the warm Indian Ocean, this area has been relatively unaffected by major climatic changes for about 30 million years, and this has resulted in high diversity and endemism, particularly in the Usambara Mountains.

Of the 190 tree species found in this regional mosaic, 92 are endemic. The non-timber forest flora is also rich with one of the best known groups being the African violets, *Saintpaulia* in the family Gesneriaceae, which has about 20 indigenous species. These species probably evolved from seed blown in from Madagascar, with each species developing to be adapted to a relatively small area of the Usambara Mountains. In cultivation, these plants hybridize readily so that there are now thousands of cultivars supporting a world trade estimated at over 30 million dollars annually in the 1980s (Kingdon, 1989).

The economically important products include cardamom, cloves, nutmeg, pepper, vanilla, coconut and cashew nut. Apart from felling trees for timber, the clearing of forest undergrowth to increase these spice plantations is one of the major threats to the biodiversity of this area. Many food crops are, and can be, grown. Animal production should be given a greater focus than it has been receiving. Composting could be introduced easily, especially with the further development of mixed farming.

East Malagasy regional centre of endemism

Eastern Madagascar (XIX in Figure 1) is dominated by the central highlands with mountains up to and above 2 000 metres above sea level. To the west, this floristic region descends to about 800 metres above sea level. To the east, the central

highlands end abruptly in steep escarpments overlooking the narrow coastal plain. The area is wet with annual rainfall exceeding 3 000 mm a year in some places. Rainfall decreases towards the centre of Madagascar, which is both drier and colder. Extensive marshes and lagoons are found in the coastal plains.

There are about 6 100 species in the floristic region, with 4 800 of them (about 80 percent) being endemic. Of the 1 000 genera, 160 (16 percent) are endemic.

The vegetation of the lowlands is rainforest, while higher up there is a mosaic of moist montane forest and drought-resistant montane forest. When deforested, the leached porous soils are covered by bamboo thickets. Compact ferralitic soils, however, are covered by grasslands following deforestation. Fire then keeps them permanently so. Therefore, the vegetation is highly vulnerable. Though there still are extensive areas of forest, deforestation is going on fast.

The main agricultural system is dominated by rice production. An emphasis on agroforestry especially along the edges of the rice fields can be used as the basis for composting and raising soil fertility. The expansion of the system of rice intensification (SRI) that was developed over 25 years ago by Fr. Henri de Laulaniè working with local farmers, also offers the possibility of improving crop production without extending cultivation into more areas of the fragile forest ecosystems. This management system has enabled poor farmers to raise their rice yields from an average of two to eight tonnes per hectare (Uphoff, undated).

West Malagasy regional centre of endemism

The West Malagasy regional centre of endemism (XX in Figure 1) is found on the flat plains inside the western coastline. The driest parts are in the south where rainfall can be as little as 300 mm per annum. The central plains generally receive about 500 mm, but this increases up to 2 000 mm per annum in the northwest.

There are about 2 400 plant species, of which about 1 900 (79 percent) are endemic. Of the about 700 genera, some 140 (20 percent) are endemic.

The vegetation varies from dry deciduous forests to deciduous thicket and grasslands. These grasslands are extensive, covering about 80 percent of the area. They are secondary in origin, having been caused by deforestation and being maintained by regular fires. Mixed agriculture is possible in most parts. Therefore, composting can be used to raise soil fertility.

HOW CAN AGRICULTURAL PRODUCTION BE INTENSIFIED IN AFRICA ?

This is a frightening time of climate change. The intensification of agricultural production in Africa based on ecological principles can take place without the use of industrially produced agrochemicals, especially fertilizers that are made from fossil fuels. Experience in Ethiopia (Edwards *et al.*, 2007; Edwards *et al.*, 2010) has shown this to be possible. Preparing compost from household and farm waste and using it to raise soil fertility has been found to be as effective as, and in the case of crops bred by smallholder farmers, to be more effective than, using chemical fertilizers to raise agricultural productivity. The role that the holistic management of domestic livestock in this recycling process and in maintaining ecosystem services needs to be much better understood and supported by professional agriculturists as well as policy-makers.

There is also the possibility of extending the improved agronomic management of crops based on the system of rice intensification (SRI) developed in Madagascar[1] (Uphoff, undated) and now spreading rapidly throughout much of south west Asia, for example in India (Anonymous, 2010). The World Bank is also supporting the SRI initiative (World Bank Institute, 2008).

But, above all, peace must prevail in Africa if the needed intensification of agricultural production is to be achieved. As Devereux (2001) pointed out, "virtually every [African] country that has suffered famine in the past twenty years has suffered a war at the same time".

1 Other crops such as finger millet, wheat, sorghum and faba bean can also be grown using the management practices described for rice. This can be called the 'System of Crop Intensification' (SCI).

EXISTING AGRICULTURAL POLICIES IN AFRICA

Following are some generalizations based on the international laws to which African countries are parties and on the documents of the African Union including those of the New Partnership for Africa's Development (NEPAD).

Article 8(j) of the Convention on Biological Diversity (CBD) recognizes the rights of local and indigenous communities. Based on this, the Organization of African Unity, which became the African Union (AU), approved its "Model Law on the Rights of Local Communities, Farmers and Breeders, and on Access to Biological Resources" in Ouagadougou in 1998 (Ekpere, 2001). Article 9 of the International Treaty on Plant Genetic Resources for Food and Agriculture gives international recognition to the right of a country to recognize farmers' rights through its domestic law.

The section of NEPAD that deals with agriculture (NEPAD, 2001) recognizes the problems of agricultural intensification in Africa as being "biases in economic policy and instability in commodity prices" as well as climate uncertainty. It sees the solution as lying in increasing investment, in "the encouragement of local community leadership in rural areas and [in] the involvement of these communities in policy [making] and the provision of services". The African Union and NEPAD subsequently translated these principles into a detailed agricultural development programme (AU and NEPAD, 2003). Recalling the known fact that most African farmers are women, of particular relevance is the emphasis given by this agricultural development programme to women in rural development. The facts on the ground in Africa, the relevant African Union and NEPAD documents and the relevant international laws thus reinforce one another to focus on communities of smallholder farmers as the main force for intensifying agricultural production in Africa.

CONCLUSION

Generally the larger and more conspicuous plants, for example flowering plants and particularly trees, and animals are relatively well known both globally and regionally (WCMC, 1992). But much less is known of most of the 'lower' and smaller organisms, and hardly anything about the micro-organisms, except for those that cause disease or are classified as pests. This general situation is also true for Africa. However, individuals and organizations from outside Africa are collecting and exploiting this diversity with little to no involvement of African scientists and local institutions. It is the smaller organisms and micro-organisms that contribute much to the overall health of ecosystems, and particularly to the essential recycling of carbon and other nutrients (WBGU, 2001). Therefore, any system of agriculture based on ecological/organic principles will work with the natural cycles rather than against them and has the inherent potential to be sustainable. This principle underlies the inbuilt robustness, or resilience, of Africa's traditional agricultural systems.

In conclusion, the fact that African agriculture is primarily subsistence and is carried out by smallholder farmers, that most of these smallholder farmers are women, that climate chaos is a real global threat to agriculture, and that food production has thus to adapt to the droughts, heavy rains and floods exacerbated by it, coupled with the fact that the subsistence farming systems in Africa are still more or less intact and thus versatile, dictate that intensification of agricultural production in Africa be ecological and that agricultural systems remain as diverse as the ecological diversity of the continent requires. The needed intensification might thus sound frighteningly complex. But, it is not if it remains centred on local farming communities who are, themselves, already as diverse in their agricultural lore as their respective ecosystems and thus need only relatively small inputs of scientific information that is new to them.

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