Bioreclamation of Degraded African Lands with Women Empowerment

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The Sudano Sahel is a semi arid region south of the Sahara with a population greater than 60 million people. Its borders are delineated by the 300-800 mm/year rain isohyets (Fig. 1). The Sahel environment is very hostile. Air temperatures are always high. During March-June they can climb to 45°C. The intensity of monsoonal rains can be higher than 100 mm/hr resulting in significant water runoff and soil erosion. The prevalent acid sandy soil is very poor in nutrients and it has very low organic carbon content (Schlecht et al., 2006).

The soil is undergoing a continuous process of erosion, mostly by wind but also by water (Manu et al., 1998). Between 80-90% of the population lives from rain-fed agriculture, producing in the rainy season (June-September) a limited number of staple crops (millet, sorghum, groundnuts, and cowpeas). Droughts result in crop failure in two out of five years. Population growth rate is around 3% resulting in diminishing area of cultivated land per household. There is a need to identify innovative alternatives for increasing agricultural productivity and income generation in such a harsh environment.

More than 50% of the Sahelian soil is degraded (Lal, 1988). Most of these degraded lands are crusted lateritic soils (Fig. 2). Both the cation exchange capacity and the water holding capacity of the degraded laterites are significantly higher than those of the predominantly sandy soils.

Women in Africa, particularly in the Sudano Sahel, are a marginalized sector of the society. There they have no or only little inheritance rights for goods, they are not allowed to own land, they have no voting rights in community matters and have a higher percentage of illiteracy than men (Mulenkey, 2002). Yet women are bearing the burden to feed their families and to help their husbands in farm operations in addition to their daily chores.

The lack of nutritional balance in the daily diets of rural Africa is becoming a matter of concern to the international community (World Bank, 1997). In dry West Africa between 13-15% of children are suffering from acute nutritional deficiency (USAID, 2006).

The Bioreclamation of Degraded Lands (BDL) system developed by ICRISAT provides solutions to these constraints. The BDL is an integrated system aiming at increasing food production and income of women through the utilization of degraded lands for production of rain-fed fruit trees and vegetables.

THE BDL SYSTEM

Degraded lands are scarified to break down the surface crust. Micro-catchments (called demi-lunes in the Sahel) are built to store run-off water (Fig. 3). The dimension of the demi-lune varies but a 2 x 3 m structure is preferred. Trees are planted in a 40 x 80 cm ridge left in the center of the open side of the demi-lune to avoid waterlogging. Demi-lunes are usually spaced at 5 x 10 m.

The area between the demi-lunes is occupied by planting pits commonly known as zaï holes (Fig. 5). A zaï is a 20 x 20 x 20 cm deep hole dug in the laterite. About 250 g of compost or manure is placed in the bottom of the zaï hole and covered with a 5 cm layer of soil. The traditional vegetables are planted in the zaï holes that are usually spaced at 0.5 x 1.0 m. The zaï collects run off water. Deep placement of the compost results in extensive growth of roots (Fig. 6) and hence in good exploitation of water and nutrients. In addition trenches (Fig. 4) are dug every 20 m down the slope to further harvest run off water.

Women Empowerment

In the Sahel women are denied the right to own croplands. Degraded lands however are in many cases community lands under the jurisdiction of the village Chief. And in many instances the village Chief can allot degraded lands to women. A women's association is created (Fig. 7). Its leadership is democratically elected. The association is registered as a legal entity and with the help of NGOs or CBOs they negotiate the ownership of a parcel of degraded lands. The association leases each of its members a plot of land in the BDL ranging from 100-300 m^2 in size. In a 200 m^2 plot there are two Pomme du Sahel trees and two *Moringa stenopetala* trees intercropped with traditional vegetables.

Reclamation of Degraded Lands

The very high rate of population growth (https://www.cia.gov/library/publications/the-world-factbook/) is putting a big pressure on the available cropland of the Sahel. For example

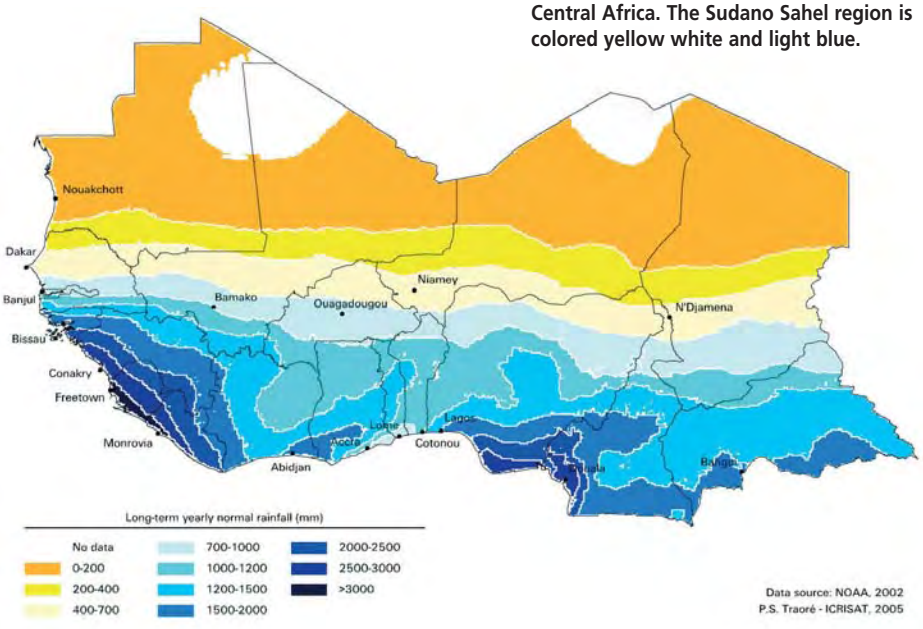

Figure 1. Rainfall map of West and Central Africa. The Sudano Sahel region is colored yellow white and light blue.

Figure 2. Degraded laterite. Surface crust prevents water infiltration resulting in a denuded landscape.

it is estimated that the average size of fields in Niger will be 0.3 ha/person in the year 2050. More than 50% of available land is degraded. The addition of cultivated land through reclamation of these degraded lands should go a long way towards solving future problems of land scarcity and food insecurity.

Coping with Climate Change

One of the predicted features of climate change in the Sahel is long dry-spells between rains. In the lateritic soils the smallest rainstorm results in water run-off that is collected in the demi-lunes to be stored in the soil. Following a rainstorm the deep-rooted trees planted in the demi-lunes use this stored water for a long period of time until the event of the following rainstorm while at the same time the shallow rooted traditional annual crops planted in the sandy soils wilt away.

In general, trees – a major component of the BDL – are much more resilient to droughts than annuals. Trees can cope better with dry spells than annual crops.

ICRISAT established in 2006 a BDL experimental field where all above-mentioned water- harvesting technologies and crops are being tried and their performance is being recorded. Soil moisture and nutrients balance is being calculated. The trees are still young and only now are starting to bear fruit. However yield data for the traditional vegetables is available. *Senna obtusifolia* can produce a yield of 1,500 kg fresh leaves per hectare. The calyx yield of Roselle is 450 kg/ha and the fresh yield of okra fruit is 1,000 kg/ha. The estimated annual value of tree and vegetable products can amount to USD 1,200/ha.

Figure 3. Water filled demi-lune planted with *Tamarindus indica.* Harvested water is stored in the soil for long periods and utilized by deep penetrating tree roots.

Figure 4. Tied trenches dug every 20 meters harvesting rainwater to be used by annuals.

CROPS FOR BDL

Tree Species

The two tree crops selected so far are the domesticated *Ziziphus mauritiana* and *Moringa stenopetala. Ziziphus mauritiana* is a small tree native to the Sahel but with a wide range of distribution all the way to Thailand. India domesticated this tree. The domesticated varieties bear fruit ten times bigger than that of the wild species. The fruit resembles a small apple in shape that prompted us to call it the Apple of the Sahel (Pomme du Sahel in French) (Fig. 8).

The trees are highly adapted to the Sahelian conditions and can be found in regions of 300 mm/y rainfall. It is tolerant to drought, salinity and waterlogging. It sends deep roots that can exploit soil water from great depths. The tree remains green until January, four months after the end of rains. It then sheds its leaves and goes dormant until the rains start again in June. A mature rain-fed tree can give a yield of up to 20 kg of fruit (Nikiema et al., 2008). Table 1 shows some of the nutrient composition of Pomme du Sahel.

Figure 5. 20 x 20 x 20 cm deep zaï holes are filled with organic matter and planted with high value traditional vegetables.

Figure 6. Specific root length of watermelons grown on Sahelian sandy soils. Same amounts of manure and fertilizers were applied in both treatments. In the "flat" treatment the amendments were spread over the surface and dug lightly into the soil. In the zaï treatment the amendments were incorporated at 20 cm depth. Horizontal bars indicate ±SE. Adapted from Fatondji et al., 2008.

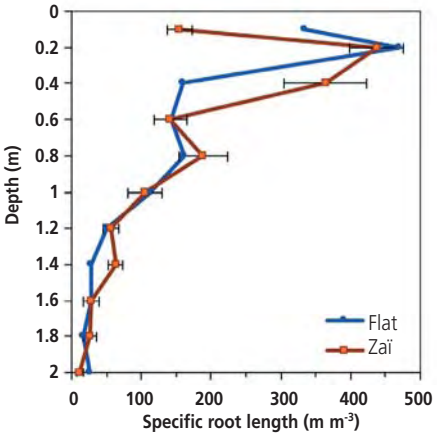

Figure 7. Village women's association - a prerequisite for sustainability and durability of the BDL.

Table 1. Nutritional composition of fresh Pomme du Sahel fruit (from Morton, 1987).

Constituent	Food value/ 100 g edible portion
Moisture	81.6-83.0 g
Protein	0.8 g
Fat	0.07 g
Fiber	0.60 g
Calcium	25.6 mg
Phosphorus	26.8 mg
Iron	0.76-1.8 mg
ß-carotene	0.021 mg
Thiamine	0.02-0.02 mg
Riboflavin	0.02-0.04 mg
Niacin	0.7-0.88 mg
Citric Acid	0.2-1.1 mg
Ascorbic Acid (Vitamin C)	65.8-76.0 mg

Figure 8. Three year old Pomme du Sahel planted in a demi-lune. Average fruit yield is about 10 kg/plant. Top left-fruit of the variety 'Kaithely' is very tasty and highly nutritious.

Pomme du Sahel has ten times the concentration of Vitamin C as compared with apple. It is rich in iron, calcium and phosphorus and in essential amino acids.

Moringa stenopetala originates in Ethiopia and Kenya. It is a large tree yielding large quantities of leaves that are consumed as a vegetable (Fig. 9). Its relative, *Moringa oleifera* (moringa or horseradish tree) from India is well known in Sahelian countries. In Niger it is the most popular vegetable (Saint Sauveur and Hartout, 2001). Moringa is one of the most nutritious vegetables known and the green leaves and immature pods and seeds are consumed. It has seven times the Vitamin C in oranges, four times the Vitamin A in carrots, four times the calcium in milk, double the protein in milk and three times the potassium in bananas (National Research Council, 2006). Moringa leaves also have very high concentration of anti-oxidants (Yang et al., 2006).

The nutritional composition of *Moringa stenopetala* is similar to that of *M. oleifera* (Table 2).

Table 2. Nutrient contents in leaves of two *Moringa* species in 100 g fresh weight (from Yang et al., 2006).

Constituent	*M. oleifera*	*M. stenopetala*
Calcium (mg)	638	711
Iron (mg)	9.2	5.4
Tocopherol (mg)	25	18
Ascorbate (mg)	249	400
ß-carotene (mg)	15	13
Protein (g)	5.7	5.8
DM (%)	24	24

In a taste test conducted by ICRISAT (unpublished) there was little difference in preferences between *M. oleifera* and *M. stenopetala*. In the Sahel, *M. oleifera* requires supplementary irrigation but *M. stenopetala* can grow in demi-lunes without supplementary irrigation.

The following additional tree species are under investigation:

Tamarindus indica (sweet tamarind). The tamarind is native to dry Africa and South and Southeast Asia. The fruit (pod) is usually sour. However in some Asian countries sweet varieties of tamarind were selected. We received four varieties of sweet tamarind from USDA-Florida and are testing these in the BDL.

Sclerocarya birrea subspecies Caffra. Sclerocarya (marula), a very drought tolerant tree native to Africa's drylands, can grow in regions of 300 mm annual rainfall. The subspecies "Caffra" that grows in southern Africa is a very robust tree. The fruit of Sclerocarya are used for juice, wine and liquor production. The kernels are used as tasty nuts. The oil extracted from the kernels is used in cosmetics. Ben Gurion University scientists together with a local NGO selected in Botswana three lines of high yielding trees with large fruit. These were successfully grafted in Niger on the local *Sclerocarya birrea* and are growing well in the degraded land (Fig. 10).

Figure 9. Ten month old *Moringa stenopetala* in BDL. High yields of nutritious leaves provide high income to farmers.

Figure 11. BDL components: Front *Senna obtusifolia* followed by Okra and Roselle. Two year old *Acacia tumida* in the back.

Acacia senegal. This Sahelian tree produces the well-known gum Arabic. ICRISAT selected high yielding *A. senegal* trees from a Sudanese provenance (giving about 1 kg gum per tree) and grafted these on local *A. senegal*.

Boswelia papyrifera. This is the Frankincense tree from dry Ethiopia.

Acacia tumida. A fast growing Australian species producing a high biomass on marginal lands of the Sahel. Used mostly for wood but its seeds can be used as chicken feed.

Lawsonia inermis - the henna shrub. Sahelian women use leaves of henna for cosmetics. A drought tolerant line was introduced from India and is used as live fences since it is not palatable to ruminants.

Vegetables

Two traditional leafy vegetables are planted in BDL systems: *Senna obtusifolia* and Roselle (*Hibiscus sabdariffa*). In a recent survey of leafy vegetables in Niger, *Senna obtusifolia* came second (after moringa) and Roselle came fourth in preferences by the rural population (Abasse et al., 2007). Some of the nutritional components of leaves of these two species are given in Table 3.

Okra (*Albemoschus esculentus*) is a very important component of the diet of Africans. In the

Figure 10. One year old *Sclerocarya birrea* sub. "Caffra" in the BDL.

Sahel it is mostly produced by women. The fruit can be dried and stored for long periods of time. The three most common annual vegetables for the BDL are shown in Figure 11. ICRISAT/AVRDC have identified a short duration cultivar from the Birni N'Konni area that is most suitable for production in the zaï holes of the BDL (Fig. 12). Unlike the case with cereals and legumes okra seeds are balanced in both tryptophane and in sulfur-containing amino acids.

Table 3. Nutritional value of two indigenous leafy vegetables used in the BDL (from Diouf et al., 1999).[a]

Constituent	*Senna obtusifolia*	*Hibiscus sabdariffa*
Crude protein	26.2	21.2
Lignin	13.7	5.3
P	0.3	0.4
Ca	2.9	0.8
K	1.3	1
Mg	0.3	0.3
Fe	0.2	0.2
Vit. A (mg/100 g)	3.7	1.9
Vit. C (mg/100 g)	120	50

[a] Vitamin A and Vitamin C are expressed on fresh weight basis. The rest on dry weight basis.

Figure 12. Okra in women's plot. The variety Konni was selected for earliness, yield and quality, yielding around 1 ton/ha fruit.

The BDL is an innovative production system of horticultural crops that provides solutions to a range of critical constraints affecting the livelihood of the rural population of the Sudano Sahel. Because of its simplicity and its many positive attributes the potential for its mass-adoption is very high.

Acknowledgments

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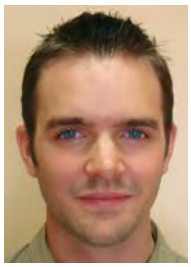

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