Zaï Practice: A West African Traditional Rehabilitation System for Semiarid Degraded Lands, a Case Study in Burkina Faso

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For degraded soil productivity, restoration, and green cover rehabilitation, it is essential to study and improve traditional farming systems, especially in the Sudano-Sahelian areas, where technical possibilities are limited. One example is the Zaï practice, a very complex soil restoration system using organic matter localization, termites to bore channels in the crusted soils, runoff capture in microwatersheds, and seed hole cropping of sorghum or millet on sandy soils. Investigation on many fields of the Mossi Plateau (northern part of Burkina Faso) has shown a range of variations of the Zaï system in relation to soil texture, availability of labor and organic matter, and relevance for rehabilitation of these degraded crusted soils. We describe a complex soil restoration system revealed during our 2 years of inquiries and experiments testing this system in two types of soil (a shallow, poor alfisol and a deep, brown tropical inceptisol). Biomass production of sorghum is reported in relation to various potential improvements of the Zaï systems and also the wild grass and shrub species that appeared after 2–7 years of a Zaï cropping system on a bare, crusted, degraded soil surface. Experimental improvements of this Zaï system on two soils confirm the possibility not only to increase the production of cereal grains (from 150 to 1700 kg ha^{-1}) and straw (from 500 to 5300 kg ha^{-1}) on deep, brown soils (eutropept), but also to reintroduce a large diversity of useful plants that may help during the fallow period and the process of degraded soil restoration. The concentration of runoff water, organic manure, and a complement of mineral nutrients in microwatersheds increased biomass production without significant change in soil properties after 2 years. This system may be useful not only to restore soil productivity but also for revegetation, e.g., 22 species of weeds and 13 species of forage shrubs included in dry dung manure (3 Mg ha^{-1} yr^{-1}).

Keywords biomass production, bush cover rehabilitation, degraded soil restoration, termite activity, traditional system, western Africa

The restoration of degraded soil productivity and rehabilitation of green cover are essential for increasing human populations of the Sudano-Sahelian African areas (Figure 1). Many programs of soil and water conservation have been developed over the past half century using methods from temperate developed countries rather than

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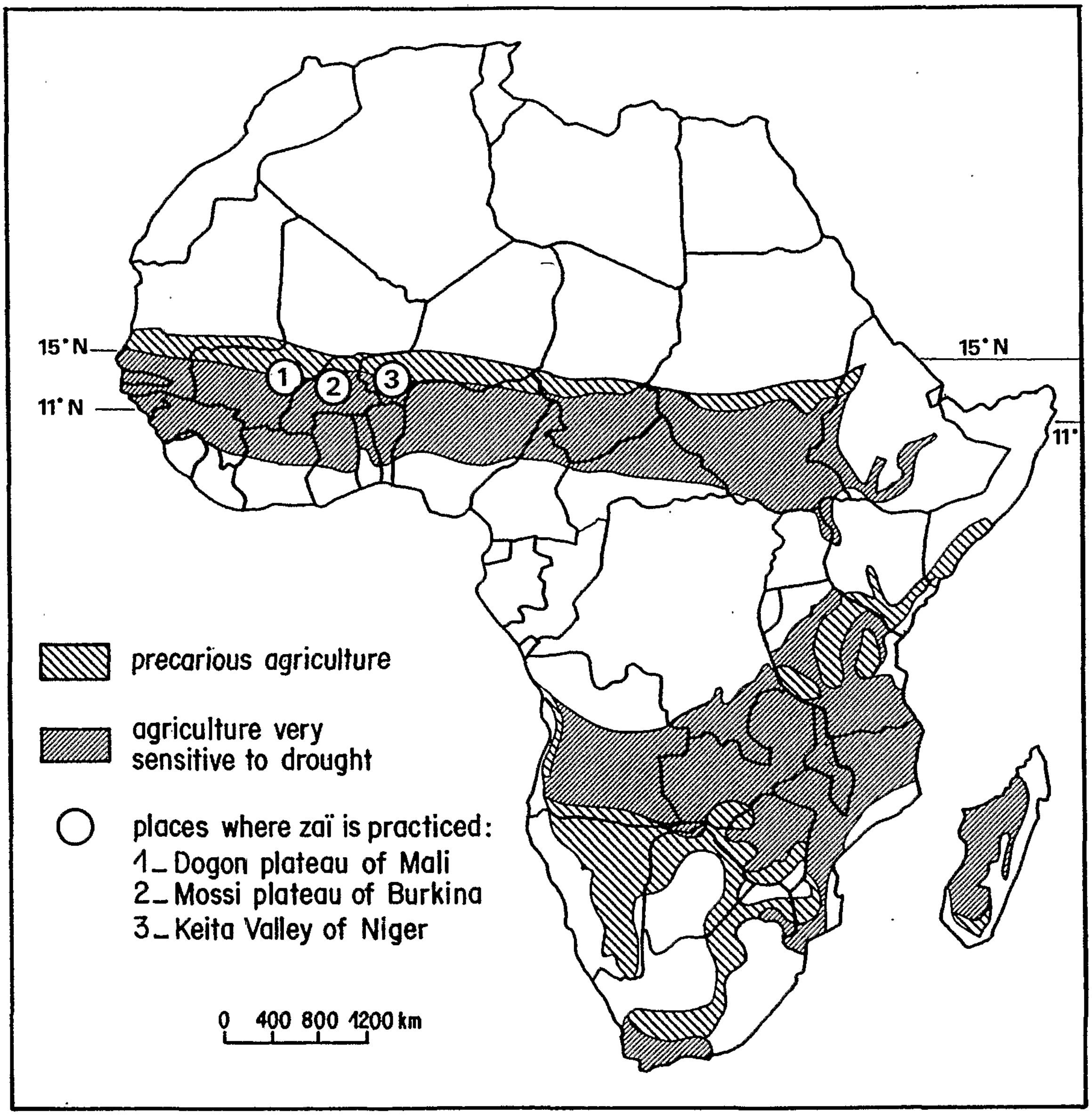

FIGURE 1 Geographical situation of Zaï areas in Africa showing locations of trials and observations and possible extension into Africa.

traditional systems better adapted to the regional physical and socioeconomical systems (Marchal, 1983). Recent studies have shown that the failure of modern methods is due not only to technical but also to cultural, social, and economical reasons. Reactualization of traditional knowledge may serve as an efficient approach to water and soil fertility management if methods are scientifically analyzed, improved and adapted to the actual demographic and socioeconomic conditions of the semiarid areas concerned (Hudson, 1992; Critchley et al., 1992; Roose, 1994).

Our research explores the Zaï traditional system, which was revived in the Yatenga province of Burkina Faso in the 1980s after the drought years of the 1970s, which struck the Sahel with a generalized decrease of 30% of average annual rainfall (Bagre, 1988). From a biological perspective, the Zaï soil restoration system, a complex cropping system concentrating runoff water and manure in micro-watersheds, may be a simple solution to restore the productivity of crusted soil surfaces ("zipellé" in the Moore language) and to rehabilitate the agroforestry cover in the Sudano-Sahelian semiarid area (Roose et al., 1992; Rey, 1994).

In this paper we describe the complex Zaï system of soil restoration revealed during our inquiries and experiments testing this system in two situations (a shallow, poor Alfisol and a deep, brown Eutropept) during the 1992 and 1993 seasons. Biomass and grain production of sorghum are reported in relation to various improved Zaï systems. We also report on the wild grass and shrub species that appeared after 2–7 years of using the Zaï cropping system on a bare, crusted, degraded soil surface.

Description of the Zaï Practices

It is not our purpose to increase admiration for traditional techniques abandoned because they are no longer adapted to actual conditions (population 5 times denser than a century ago, salaries higher in the town than in the country). Our aim is to understand the function of traditional practices, reasons for their variations and extension into the Sudano-Sahelian area, their success on the Mossi Plateau (Burkina Faso), on the Dogon Plateau (Mali), and in the Keita Valley (Niger), and their failure elsewhere, in particular, in the Sudanian area of Cameroon, where annual rains exceed 1200 mm. Analysis of these practices may help us to improve them by supplementation of modern technologies like complementary mineral fertilization, herbicides, pesticides, selected seeds, and mechanization. Conversely, observation of efficient traditional practices may help us to diagnose the physical and human environment.

In the Moore language, "Zaï" is derived from the word "zaïégré," which means "to wake up early to prepare the seedbed-land." The method was used to rehabilitate abandoned land, degraded by many years of cropping or grazing, completely denuded, and crusted, and where runoff is so strong that it washes away seeds and organic residues that could rehabilitate the fallow. Since the study by Marchal (1983), desertified areas have increased up to 11% in 20 years in the Yatenga province, despite considerable precipitation (400–700 mm mean annual rainfall).

Formerly, Zaï practices were used by the poorest farmers, who had only unfertile land and few tools. This method was often abandoned during wet years (e.g., 1950–1970), replaced by new mechanical seedbed preparation, extension to new lands and management of irrigated lowlands.

The Zaï practice and one "agrosylvopastoral variant" observed in Burkina Faso are illustrated in Figure 2. In this restoration practice (Figure 2*a*), the land must be prepared early during the dry season by digging basins 20–40 cm in diameter and 10–15 cm deep in order to collect runoff water. The remaining surface is crusted (mineral or cryptogamic crust) and functions as a seal (Wright, 1982). The pit size increases where soils are superficial or gravelly and decreases on the less permeable loamy-clay soils (Kabore & Valdenaire, 1991). These microcatchments trap sand, loam, and organic matter brought by Harmattan, the wind coming from the Sahara Desert. Stone bunds fence the field in order to control the runoff, which is extensive on these crusted lands.

As early as the first storms of April (Figure 2*b*), the farmer puts down one or two handfuls of dry dung (about 1–3 Mg ha^{-1} of air-dried organic matter) or a mixture of roughly decomposed animal feces, litter, compost, small branches, ashes, and all kinds of farm residue. Termites (Trinervitermes), attracted by organic matter, dig galleries at the bottom of the pits that they transform into funnels (Roose, 1976). There runoff water infiltrates deeply and creates deep moisture pockets, protected

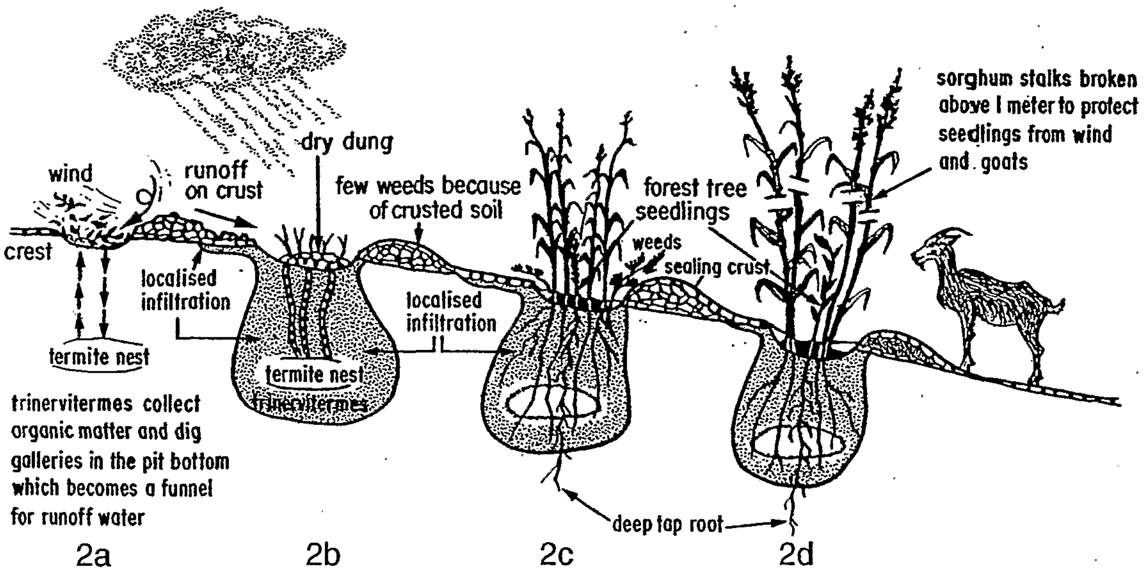

FIGURE 2 Zaï practice for soil and green cover rehabilitation.

from quick evaporation. This way, the complex Zaï system allows water to concentrate in the seed hole. Moreover, this water is enriched by runoff and nutrients from the organic matter transformed by termites.

After the first storm, the whole family sows one dozen sorghum seeds in seed holes on clay soil or millet on sandy or gravelly soils: their combined energy is able to break the crust deposited at the bottom of the pits. This seedbed preparation technique on degraded lands ("zipellé" means sterile, crusted, white-surfaced land) decreases the surface to be weeded to the seed hole for the first year and can lead to the production of 500–1000 kg ha^{-1} of cereal grains and 2–4 Mg ha^{-1} of straw (used for cattle and domestic purposes), depending on rainfall and soil fertility (Roose, 1976). In the next years, farmers open new pits and put in more dry dung. However, when they are in a hurry or there is a lack of manure, farmers uproot the sorghum rootstock and put it on the crusted surface (where it is attacked by termites), till the bottom of the primitive pit, and sow the cereal directly in the seed hole. This intensive system does not accelerate soil degradation. On the contrary, after 5 years, the entire surface has been improved by tillage and termites, which dig holes through the crusted surface looking for organic matter (Roose, 1976). This system allows for the maintenance of organic manure in the seed holes, which the farmer covers with a handful of soil.

Although the general pattern remains as described, each farmer has his own version of Zaï practices adapted to his farm conditions. Some farmers observed about a dozen shrub species germinating from the dung; during weeding operations, they retain one seedling for every five seed holes (Figures 2*c* and 2*d*). This density escapes the eyes of goats because sorghum stalks are cut above the height of the livestock. After 10 years or so, various forage shrubs, including many legume species, recolonize these sites and help maintain cereal production by improving soil fertility.

Physical Environment

The studies were made in the Yatenga and Passore provinces in the northern part of Burkina Faso (Figure 1). This area is Sudano-Sahelian shrub-savanna resistant to a long (6–8 months) dry season with prevailing Saharian winds called Harmattan.

During the short rainy season (June–September), annual rainfall varies from 400 to 700 mm, while potential evapotranspiration exceeds 1900 mm.

The regional topography (Figure 3) consists of a rolling surface dominated by hills and ironpan crusted plateaus, a short rock scree, and a long glacis (1–3% slope), first gravelly, then sandy-loam on ironpan, and finally, clay-loam in the wide valley. This sequence controls soils and vegetation distribution as well as local land-use practices.

Soils of this region (Figure 3) were studied by the Institut de Recherche pour le Développement (IRD), formerly ORSTOM (Marchal, 1983). It was found that rego-soils occur on the hilltops and the upper part of the glacis; alfisols (leached ferruginous tropical red soils) cover most of the glacis; hydromophic soils are limited to the valley bottoms; and tropical brown soils (Eutropept) are developed on sandy-clay weathered green rocks (Soil Survey Staff, 1975).

Ferruginous soils (Alfisol), the most frequently used for cropping, have severe limitations, including poor structural stability and high erodibility of the topsoil. They are rich in silt and loam, with low organic matter, nitrogen, phosphorus, and potassium contents, low cation exchange capacity, and a strong tendency to acidification. Finally, they show low water storage capacity as a result of kaolinitic clay, gravels, and ferruginous hardpans near the surface. Despite periodic drought, cropping is today extending to the superficial gravelly soils of the top of these toposequences.

The recent labor shortage related to migrations (by 1980, 40% of 20–40-year-old men had emigrated (Billaz, 1980) and gold mining activities during the dry season have limited investment in farming activity in this region. Dugué (1989) observed that in many cases, labor was carried out by women (60%), "old" men over 45, and children under 16. Cereals, peanuts, sesame, and niebe are more subsistence than commercial crops. Capitalization is chiefly dependent on stocking and

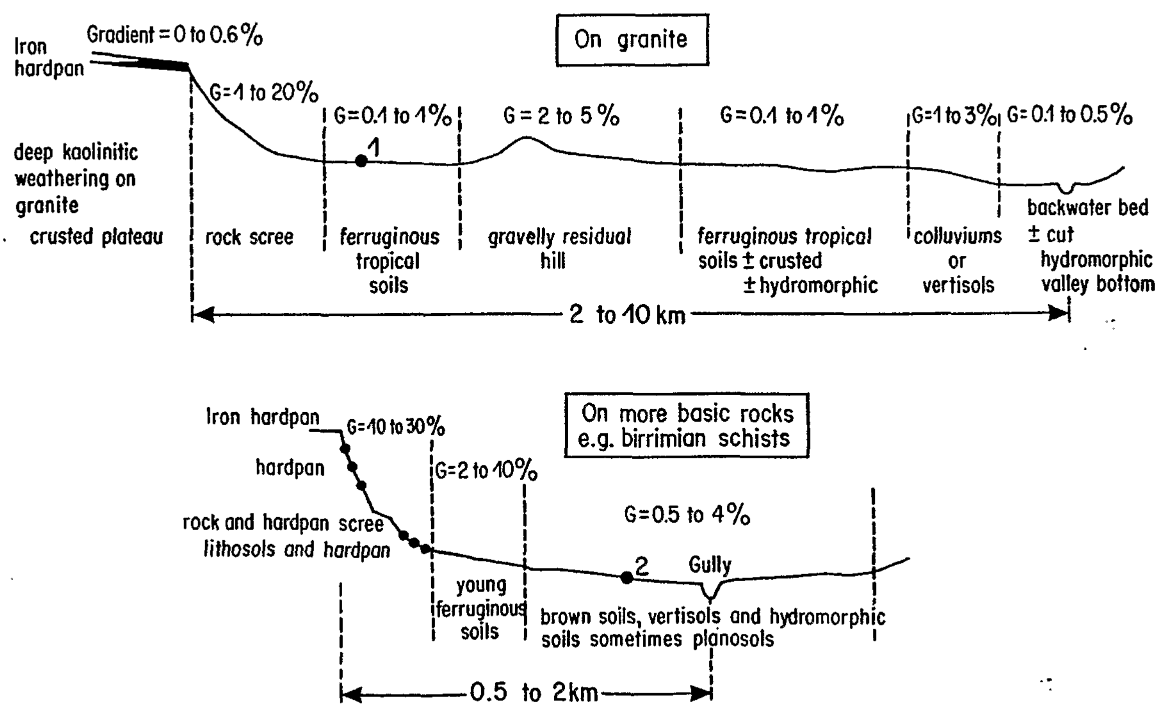

FIGURE 3 Typical soil catenas of the Mossi plateau (Burkina Faso) showing positions of restoration trials of Pouyango and Taonsongo.

TABLE 1 Physico chemical characteristics of the topsoils of red Alfisol (Pouyango) and brown Eutropept (Taonsongo)

	Shallow, red Alfisol	Deep, brown Eutropept
C total (g kg^{-1})	11	7
N total (g kg^{-1})	0.7	0.6
P (mg kg^{-1})	0.32	0.31
Ca ($cmol_c$ kg^{-1})	4.3	14.1
Mg ($cmol_c$ kg^{-1})	0.7	4.6
K ($cmol_c$ kg^{-1})	0.11	0.09
pH	5.5	5.9
CEC($cmol_c$ kg^{-1})	5.7	20.3
Saturation rate (%)	89	93
Clay (g kg^{-1})	243	374
Loam (g kg^{-1})	384	370
Sand (g kg^{-1})	376	258

C total, g kg^{-1} (Casumat); N total, g kg^{-1} (Kjeldahl); P, mg kg^{-1} (Bray I); exchangeable cations (KCl extract, $cmol_c$ kg^{-1}), clay (0–2 μm), loam (2–50 μm), and sand (50–2000 μm)g kg^{-1}.

income from emigrant workers. Investment in farming is limited because profit is low and retarded due to unpredictable conditions (drought, diseases, absence of attractive market, etc.) (Dugué, 1989).

The objective of this study was to determine the role of initial soil fertility and implementations like organic matter and mineral nutrients on the possibility to restore the productivity of degraded soils and to rehabilitate the sylvopastoral bush fallow in this semiarid region.

Materials and Methods

During 1992 and 1993, possibilities for biomass productivity improvement were tested on two fields. We measured the impact of digging the pits and of organic and mineral fertilizing on the biomass production (grain and straw) of a sorghum crop (var. IRAT 204). The impact of Zaï practices on shrub and herb diversity were evaluated after 2 and 7 years.

Experimentation was conducted on two degraded sites (zipellé) (Figure 3, Table 1): (1) a ferruginous tropical soil (Alfisol), 30 cm deep on a lateritic ironpan at the village of Pouyango (12°49′N; 2°8′W), 10 km northeast of Yako city, and (2) a brown tropical soil (Mollisol), deeper (>120 cm) and richer (on green schist), at the

TABLE 2 Rainfall at Pouyango and Taonsongo sites in 1992 and 1993

	Rainfall in 1992		Rainfall in 1993	
	Total (mm)	Rainy days	Total (mm)	Rainy days
Pouyango (Alfisol)	706	27	632	23
Taonsongo (brown Eutropept)	563	40	466	34

TABLE 3 Total carbon (Casumat, g kg^{-1}), nitrogen (Kjeldahl, g kg^{-1}), phosphorus (Bray I, mg kg^{-1}), total potassium (g kg^{-1}), and available Ca, Mg, and K (g kg^{-1}) of various organic fertilizers

	C total	N total	P total	K total	C/N	Ca	Mg	K
Compost	75	7	0.5	n.a.	10	3	0.6	0.4
Manure	174	3	0.5	n.a.	47	1	0.4	6.0
Leaves								
Azadirachta[a]	529	27	1.6	73	20	n.a.	n.a.	n.a.
Piliostigma[a]	555	14	1.1	28	38	n.a.	n.a.	n.a.

n.a., not available.
[a] *Azadirachta indica* leaves used in this experiment as compared to the leaves of *Piliostigma reticulatum.*

village of Taonsongo (12°48′N; 2°15′W) 5 km southeast of Yako. The distance between them is less than 10 km.

Although the mean annual rainfall is 150 mm lower in the brown soil case, drought impact has been less important because it rains more often, the soil is deeper, and the storage capacity is much larger than in the superficial ferruginous soil case (Table 2). Furthermore, the 1993 rainfall amount was 100 mm less than in 1992, but the rain distribution pattern was better.

TABLE 4 Grain and biomass production (kg ha^{-1}) on the shallow Alfisol in 1992 and 1993 at Pouyango

	1992			1993		
Treatment	X	±S.D.	Tukey-Kramer test ($P < 0.05$)	X	±S.D.	Tukey-Kramer test ($P < 0.05$)
			Grain Production			
Control	63	31.3	A	22	17.1	a
Pit	150	119.9	a	29	22.8	a
P + leaves	184	164.7	a	83	36.0	ab
Compost	690	48.6	b	257	127.5	abc
Mineral fertilizer	829	203.9	b	408	217.4	bcd
Compost + mineral fertilizer	976	173.2	b	550	265.3	cd
			Biomass Production			
Control	857	326.6	A	292	91.8	a
Pit	1213	581.1	a	375	243.1	a
P + leaves	1368	493.9	a	1000	309.6	ab
Compost[a]	1665	387.2	b	1542	651.8	abc
Mineral fertilizer	3302	870.0	b	2375	1460.6	bc
Compost + mineral fertilizer	3545	505.0	b	3167	1514.9	c

[a] Compost: 3 Mg ha^{-1} of a mixture of dry dung manure, straw, and crop residues roughly composted during 3 months of the dry season.

TABLE 5 Grain and biomass production (kg ha^{-1}) on the deep, brown Eutropept Soil in 1992 and 1993 at Taonsongo (Burkina Faso)

Treatment	1992 X	1992 ±S.D.	1992 Test[a]	1993 X	1993 ±S.D.	1993 Test[a]
Grain Production						
Control	150	±154	a	3	±0.6	a
Pit	200	±63	a	13	±4.2	a
Pit + leaves	395	±151	ab	24	±7.3	a
Compost[b]	654	±145	abc	123	±82.5	a
Mineral fertilizer	1383	±236	bc	667	±256.3	b
Compost + mineral fertilizer	1704	±305	bc	924	±346.8	b
Biomass Production						
Control	946	±529	a	167	±75	a
Pit	1329	±549	a	292	±49	a
P + leaves	1990	±207	ab	875	±172	ab
Compost[b]	2843	±945	abc	1417	±511	bc
Mineral fertilizer	4839	±1105	bc	2375	±706	bcd
Compost + mineral fertilizer	5333	± 1490	bc	3250	±857	cd

[a] Tukey-Kramer test ($P < 0.05$).
[b] Compost: 3 Mg ha^{-1} of a mixture of dry dung manure, straw, and various crop residues roughly composted during 3 dry months.

The experimental trial compared six treatments with six repetitions organized in randomized blocks.

Trial T: the reference sorghum sown traditionally without any soil management
Trial P: sorghum sown in a pit without any manure
Trial F: sorghum sown in a pit after burying 3 Mg ha^{-1} of fresh leaves of *Azadirachta indica* L. (neem), a well-known Indian tree introduced and widely planted in semiarid Africa
Trial C: sorghum sown in a pit after burying 3 Mg ha^{-1} of straw compost
Trial E: sorghum sown in a pit after burying mineral fertilizer NPK (10-20-10 kg ha^{-1})
Trial CE: same as trial E plus 3 Mg ha^{-1} of compost and NPK (10-20-10) kg ha^{-1}.

The richness of composted manure and noncomposted leaves is defined in Table 3. There are obvious deficiencies in total phosphorus and nitrogen.

Results

Biomass Production on Shallow Red Alfisol (Pouyango)

All treatments improved the yield of grain and also of cereal straw for both years, but the second year, the yield was only 50% that of 1992. It is possible that water storage was decreased during the second year, but perhaps more likely, the nutrient

TABLE 6 List of herbs and wood plants observed in the fallow after 7 and 2 years of Zaï practice

Herbs	Shrubs and trees
Acanthospermum hispidum DC	*Acacia albida* Del.
Andropogon gayanus Kunth	*Acacia nilotica* (L.) Willd.
Boerhavia diffusa L.	*Adansonia digitata* L.
Brachiaria ramosa (L.) Willd.	*Balanites aegyptiaca* (L.) Del.
Cassia obtusifolia L.	*Calotropris procera* (Ait.) R.Br.
Corchorus olitorius L.	*Combretum aculeatum* Vent.
Corchorus tridens L.	*Combretum micranthum* G.Don.
Cyperus esculentus L.	*Diospyros mespiliformis* Hochst
Dactyloctenium aegyptiacum (L.) Willd.	*Guiera senegalensis* J.F. Gmel.
Eragrostis tremula Stend.	*Lannea microcarpa* Engl. & K. Krause
Euphorbia hirta L.	*Piliostigma reticulatum* (DC) Hochst
Ipomea eriocarpa R.Br.	*Sclerocarya birrea* (A.Rich.) Hoehst
Kyllinga squamulata Thonn.	*Ziziphus mauritiana* Lam.
Mariscus cylindristrachyus Stend.	
Mollugo nudicaulis Lam.	
Panicum laetum Kunth	
Pennisetum pedicellatum Trin.	
Rottboellia cochinchinensis (Lour.) Clayton	
Schoenefeldia gracilis Kunth	
Setaria pumila (Poir.) Roem.&Schult.	
Spermacoce stachydea DC	
Zornia glochidiata Reichb. ex DC	

availability was limited, in part, because of the large number of weeds that occurred (Table 4). Pitting alone and improving water disposal increased the grain and biomass production, but it was not statistically significant ($P < 0.05$), suggesting that water is not the only limiting factor for cereal production.

Burying fresh tree leaves of *Azadirachta indica* increased the production of grains and crop biomass, but it was statistically significant only during the second year, after nutrients contained in the green leaves were released. The use of compost significantly increased grain and straw production in both years. However, chemical analysis of the compost used (Table 1) shows that it is poor in phosphorus and nitrogen.

The small dose of mineral fertilizer (NP = 10 + 20) greatly increased the production of grain and cereal straw (2–6 times). The addition of mineral fertilizer with composted manure gave the best yields in both years.

Biomass Production on a Deep, Brown Inceptisol (Taonsongo)

Similar results were obtained from the six treatments in regard to crop biomass production. However, yields were generally better on the deep, rich brown soil than on the superficial poor ferruginous one except for the treatment pit + leaves (Table 5). The addition of compost significantly increased biomass production during the first year, but mineral fertilizer combined with organic compost was the only treatment that resulted in significantly increased production in the second year.

Increase of Plant Diversity: Rehabilitation of Herbaceous and Bush Fallow

Although the ground was initially bare, after 2 years of cropping, an inventory shows the presence of numerous leguminous tree and herbs (Table 6). The young tree seedlings grow rapidly due to manure and runoff water accumulation in micro-catchments. The Zaï practice may also result in increased soil biological activity as implied by the presence of plant species colonizing the field (Table 6). Dry dung contains various species of seeds eaten by animals, which after being "treated" by the gastric acids of these ruminants, germinate early and benefit from high water and nutrient supply in the pits and from the protection against goats provided by cereal straw (Roose, 1994).

The Zaï practice also had a deep impact on the diversity of the herbaceous population of these degraded lands (Table 6). The most common herbs are *Dactyloctenium aegyptiacum* (L.) Willd., *Ipomea eriocarpa* R. Br., *Pennisetum pedicellatum* Trin., *Schoenefeldia gracilis* Kunth, *Spermacoce stachydea* DC, and *Zornia glochidiata* Reichb. ex DC. All these species are tolerant to poor nutrient conditions. The seeds come with the wind or in dry dung even if the crusted areas remain bare some years, the pit environment improves seed germination and dissemination, so that Zaï has a very positive impact on the revegetation of bare degraded areas.

Discussion

The data presented here confirm the possibility of restoring the productivity of cereal crops on degraded soils by using Zaï practice, but the efficiency of this investment is highly dependent on the water and nutrient storage capacity of the soil profile. The yield decrease in 1993 was more important for treatments without mineral fertilizer ($<1/5$) than when mineral fertilizers were included (yield in 1993 = 1/2 yield in 1992). As the rainfall distribution was better in 1993, one may conclude that the decrease in production observed was due to a lack of nutrients. This decrease was also more pronounced when weeds developed in 1993.

The capture of runoff water (and its solid load) allowed only a limited increase of biomass production as long as the nutrient level was not improved. The composted manure is not rich enough in phosphorus, the most limiting nutrient in these soils (Pieri, 1989). To increase availability of phosphorus in soils rich in free iron, it is necessary to add crushed natural phosphorus carbonate rocks into the manure compost. Nitrogen is the next limiting factor (Pieri, 1989). Introducing leguminous plants in fallows is an efficient way to reduce this deficiency in natural conditions, but without phosphorus, legumes grow very slowly. As manure in this area is generally a combination of dry dung mixed with a little straw and family (kitchen) residues exposed to sun and rainfall (leading to high N losses), the C/N ratio is high, and plants need a complement of nitrogen for optimization of biomass production in relation to the water disposal.

Burying fresh leaves of *Azadirachta indica* (neem) only slightly improved crop biomass production, despite their relatively high nitrogen content. The nutrients actually released from the leaves no doubt were limited by the low rate of mineralization in the soil. In these trials the leaves were not well decomposed at the end of the season, but their positive impact increased in the second year. (In Table 3 the contents of leaves from *Piliostigma reticulatum* (DC) Hochst., a leguminous shrub widespread locally and frequently used as green manure by Mossi farmers, is reported as a point of reference to the neem.) The manure compost was much more efficient but still much less than when manure is associated with mineral fertilizer, even at a very low rate.

After 2 years, it was not possible to distinguish any evolution of the topsoil characteristics: all incoming nutrients were apparently used for plant growth. Thus it appears more pertinent to discuss soil productivity restoration than soil restoration per se: our sampling and soil analysis techniques were not sensitive enough. It is clear that the mechanical approach (pitting + tillage) is not sufficient to rehabilitate these degraded soils. It was the combined practice of capturing surface runoff, burying composted organic matter and mineral fertilizers, termite boring activities, and management of the topsoil that resulted in the production of 1000–1700 kg ha^{-1} of grain and 3000–5300 kg ha^{-1} of cereal straw as compared to the control treatment, which yielded only 200 kg ha^{-1} of grain and 300 kg ha^{-1} of straw.

The Zaï practice also has a significant impact on plant diversity of these desertified lands. Even if the crusted areas remain bare a few years, the pit environment increased seed development and dissemination, thereby accelerating fallow rehabilitation.

The advantages of Zaï chiefly concern runoff management, seed and manure conservation, fertility, and available water concentration in seed holes at the beginning and end of the rainy season. Increasing the field surface rugosity, Zaï slows runoff and wind velocity and helps catch organic debris and fine particles and thus enables the maintenance of a productive argopastoral bush-woodland. Finally, the Zaï practice extends cropped areas to degraded fields, increases cereal yields, and secures biomass productivity.

However, Zaï practices have their limitations. They can reduce the impact of a drought for up to 2–3 weeks if and only if water-holding capacity of the soil is sufficient (minimum 50 mm). Conversely, in the event of excessive rains, cereal often suffers from pit clogging and nutrient leaching, as observed in Cameroon (E. Roose, unpublished data). The optimal condition for Zaï efficiency seems to be limited to the Sudano-Sahelian area (400–800 mm), but even that may be related to the type of plants and soils present locally (Figure 1). The Zaï extension is also limited by labor and manure availability Zaï is labor intensive. It requires about 300 hours ha^{-1} of hard work with a pick axe, the transport of 3000 kg ha^{-1} of dry dung, and the management of stone bunds all around the field to control runoff. Therefore a sturdy cart and plenty of willing laborers are required.

Roose and Rodriguez (1990) proposed two improvements to the traditional Zaï practice. First is a crossed subsoiling, each 80 cm deep, with one tooth penetrating 15–18 cm under the topsoil crust just after harvesting. This takes only 11 hours ha^{-1} with oxen well fed with crop residues available at that season, and reduces the time to dig the pits by half. A second improvement is to introduce a mineral complement: indeed, dry dung contains very little nitrogen and phosphorus (Table 1). With a double dose of manure, Kabore (1994) showed it is possible to produce 1000 kg ha^{-1} of cereal grains, and even 1500 kg ha^{-1} with a mineral complement of 10 kg and 20 kg ha^{-1} for nitrogen and phosphorus, respectively. These yields are double or triple the regional average yield of 600 kg ha^{-1}.

Conclusions

In the Sudano-Sahelian area, soil degradation comes from the disequilibrium of organic matter and nutrient balance after cropping extension and overstocking on fragile soils. On these crusted grounds, intensive runoff inhibits or prevents the soil and vegetation restoration processes in fallows. The Zaï traditional practice allows the restoration of soil productivity from the first year, as it applies the following six "rules" to quickly restore degraded soils: runoff management, macroporosity restoration and stabilization, topsoil revitalization, pH maintained above 5, and correction of nutrient deficiencies.

Inquires in the Yatenga region have revealed the diversity of Zaï practices that contribute to the restoration of deep rooting by plants, improved water infiltration capacity of soils, and use of biological activity (manure, termites, weeds and forage bushes, cereals) to concentrate water and nutrients in the pit around the cereal clumps. The "agrosylvopastoral variant" established a system well adapted to a sustainable management of these semiarid zones.

Combined with composted organic manure and a light mineral fertilization (N-P), the Zaï practice allows regional cereal production to improve significantly, while also reducing food insecurity and pressure on the arable land. More research is needed to improve traditional systems and to restore the natural agrosylvopastoral processes and, above all, soil fertility in semiarid degraded areas.

References

Bagre, J. 1988. Diguettes en pierres et poches d'eau: Rawana/Yatenga, Burkina Faso, pp. 221–238, in *Le sahel en lutte contre la désertification: Leçons d'expériences.* GTZ, Ministère de la Coopération en Allemagne, Bonn, Germany.

Billaz, R. 1980. Sabouna, un village du Yatenga: Ses hommes, ses cultures, pp. 28–40, in R. Billaz, ed., *Les systèmes de cultures.* Institut pour le Développement, Ouagadougou, Burkina Faso.

Critchley, W., C. Reij and S. Turner. 1992. *Soil and water conservation in sub-Saharan Africa: Toward sustainable production by the rural poor.* International Fund for Agricultural Development, Center for Development Cooperation Services, Free University, Amsterdam, Netherlands.

Dugué, P. 1989. *Possibilités et limites de l'intensification des systèmes de culture vivrière en zone Soudano-Sahélienne. Cas du Yatenga (Burkina Faso). Documents Systèmes Agraires 9.* Centre International de Recherche en Agriculture pour le Développement (CIRAD), Montpellier, France.

Hudson, N. W. 1992. *Land husbandry.* Bastford, London.

Kabore, V. 1994. *Amélioration de la production végétale des sols dégradés (zipelle) du Burkina Faso par la technique du Zaï.* Thèse de Doctorat, Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland.

Kabore, V., and S. Valdenaire. 1991. *Contribution à l'étude du Zaï, pratique culturale réhabilitée au Yatenga.* Mémoire. Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland.

Marchal, J. Y. 1983. *Yatenga, dynamique d'un espace rural Soudano-Sahélien (Haute-Volta). Travaux et Documents 167.* ORSTOM, Paris.

Pieri, C. 1989. *Fertilité des terres de savane: Bilan de 30 ans de recherche et de développement agricole au sud du Sahara.* Ministère de la Coopération Française et Centre International de Recherche en Agriculture pour le Développement, Paris.

Rey, C. 1994. La conservation des eaux et des sols donne des résultats. *Haramata* 25:11–13.

Roose, E. 1976. *Contribution à l'étude de l'influence de la mésofaune sur la pédogenèse actuelle en milieu tropical.* ORSTOM, Montpellier, France.

Roose, E. 1994. Introduction à la gestion conservatoire de l'eau, de la biomasse et de la fertilité des sols (*GCES*). *Bulletin Pédologique FAO 70.* FAO, Rome.

Roose, E., P. Dugué, and L. Rodriguez. 1992. La GCES: Une nouvelle stratégie de lutte antiérosive appliquée à l'aménagement de terroir en zone soudano-sahélienne du Burkina Faso. *Bois et Forêts des Tropiques* 233:49–61.

Roose, E., and L. Rodriguez. 1990. *Aménagement de terroirs au Yatenga. Quatre années de Gestion Conservatoire de l'Eau et de la fertilité des Sols (GCES): Bilan et perspectives.* ORSTOM, Montpellier, France.

Soil Survey Staff. 1975. Soil taxonomy. *U.S. Department of Agriculture Handbook 436.* USDA, Washington, D.C.

Wright, P. 1982. *La gestion des eaux de ruissellement.* Office Régional de Développement du Yatenga Projet Agroforestier, Ouahigouya, Burkina Faso.

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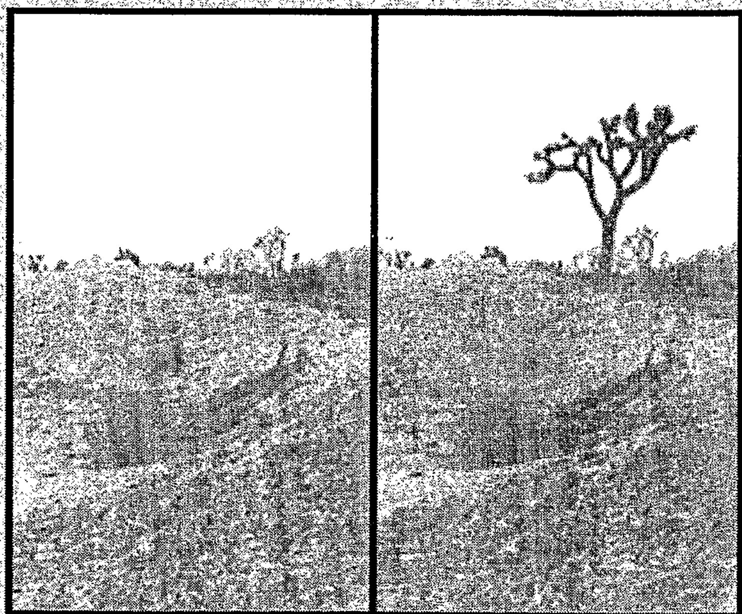

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