Potential contributions to food security from scaling up agroforestry and improved soil and water management practices in Burkina Faso

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Executive Summary

This paper documents the evidence of the impact and benefits associated with agroforestry and other improved land management practices used by farmers in the Central Plateau of Burkina Faso to cope with land degradation. It identifies opportunities to scale up their adoption to boost crop yields and contribute to increased food security. The report presents a methodology to assess the potential land area suitable for scaling up agroforestry and soil and water conservation practices based on an analysis of soil characteristics, rainfall, land cover, and population density.

Over the last 30 years, Burkina's land and its capacity to support agricultural production have been negatively impacted by land degradation. In 2002, 11% of the land was estimated to be "very degraded" and 34% "moderately degraded". While conventional wisdom would categorize degraded lands with low to no agricultural potential and predict their continuous expansion, observations on the ground are demonstrating that, with special care, these lands can be and are reclaimed to support farmers' livelihoods. With an increased density of trees in some landscapes, some parts of northern Burkina Faso are showing an agricultural revival. This reversal in trajectory can be attributed to many different efforts by a multiplicity of actors, among others, the adaptability and innovativeness of farmers, the strengthening of land and tree tenure, and expansion of activities to support decentralized natural resource management and farmer innovation. With little financial resources, farmers have improved traditional soil and water conservation practices (e.g., zaï, contour stone bunds) and adopted other

innovative techniques to restore the productivity of the land (e.g., using farmer managed natural regeneration to restore agroforestry systems).

These efforts have slowed down the rate of land degradation by recovering tens of thousands of hectares of degraded land deemed lost to agricultural production. To have decisive gains in agricultural production and productivity at the national level, there is a need to accelerate and scale up the implementation of practices that have been adopted by farmers and proven effective in reclaiming degraded cropland and in boosting the agricultural productivity of the land. The paper discusses the current uptake of these practices in the Central Plateau and assesses the potential for scaling them up at the national level based on readily available data by assessing where each of these agricultural practices could be implemented and what their potential is in terms of agricultural production.

Using the GIS analysis documented in this paper, the authors estimate that 4.9 million ha of land are highly suitable for the adoption of zaï, and 7.5 million ha of land are highly suitable for the adoption of agroforestry using farmer managed natural regeneration. Based on the observed impacts on crop yields by farmers using these practices in Burkina, the widespread adoption of these two improved practices at this scale could contribute an estimated 2.7 million additional tons of cereal each year.

The paper also reports on the constraints to scaling up these practices that have been identified by local, regional and national actors involved in the promotion of these practices during discussions that took place at a workshop conducted in March 2013 in Ouagadougou. The “Atelier National de Plaidoyer sur la Régénération Naturelle Assistée” was organized by Réseau MARP Burkina and attended by 50 participants, including farmer innovators, government officials, researchers and NGOs. The challenge most repeatedly identified is that farmers are vulnerable to the usurpation of the fruits of their investment as a result of a weak natural resource rights framework. Indeed, land tenure insecurity is a daily challenge for farmers who strive to implement improved soil and water management practices without secure property rights to the land or the trees they have been caring for over the years.

The report concludes with several recommendations to address the constraints in the national workshop, and a summary of the steps outlined by local stakeholders to prepare a national agroforestry strategy. The following three overarching recommendations were identified: (1) Provide a supportive policy and legal framework with clear property rights to foster implementation of agroforestry and improved soil and water management practices; (2) Provide financial support to farmers implementing agroforestry and improved soil and water management practices; and (3) Foster a community of practice and build the capacity of farmers, government and civil society groups. Workshop participants pledged to work together to define and implement a national agroforestry strategy to address key constraints and to support the scaling up.

1. Introduction

This paper documents the evidence of the impact and benefits associated with agroforestry and other improved land and water management practices implemented by local farmers in the Central Plateau of Burkina Faso to cope with land degradation. It also highlights the key barriers to scaling up these practices and recommends ways to overcome the most important ones. It also identifies opportunities to scale up their adoption to boost crop yields and contribute to increased food security.

This paper is based on existing literature and compiles the findings of the "Atelier National de Plaidoyer sur la Régénération Naturelle Assistée" organized by Réseau MARP Burkina in March 2013. This workshop convened farmer innovators who have played a leading role in developing the techniques of "zai" and agroforestry, high-level officials from the Ministry of Agriculture and Food Security and from the Ministry of Environment and Sustainable Development, and various local and international civil society organizations. At the workshop the participants heard of various success stories of agroforestry and related soil and water management practices, and discussed the enabling factors and constraints to these individual farmers' success. They also sketched preliminary recommendations regarding the establishment of a national strategy and incentives to promote agroforestry.

2. Context for soil and water management in Burkina Faso

Burkina Faso is a landlocked country in West Africa with an area of 274,200 km^2 and a population of more than 16 million people in 2012, of which 80% live in rural areas (World Bank 2013).

Almost half of Burkina's population (46%) is poor with a significant difference between the rural and urban percentage of people living in poverty at 51% and 16% respectively (WB 2013).

Burkina Faso's economy is highly dependent on agriculture. In 2011, it accounted for 34% of the Gross Domestic Product. Dominated by small-scale family farms, the sector employs about 85% of the workforce (WB 2013). Forty-three percent of the land area is under some form of agriculture, being primarily rain-fed cropland and a mosaic of land cover used for crops and livestock (percentage based on FAO 2011, also see Map 1 for a spatial distribution of agricultural land).

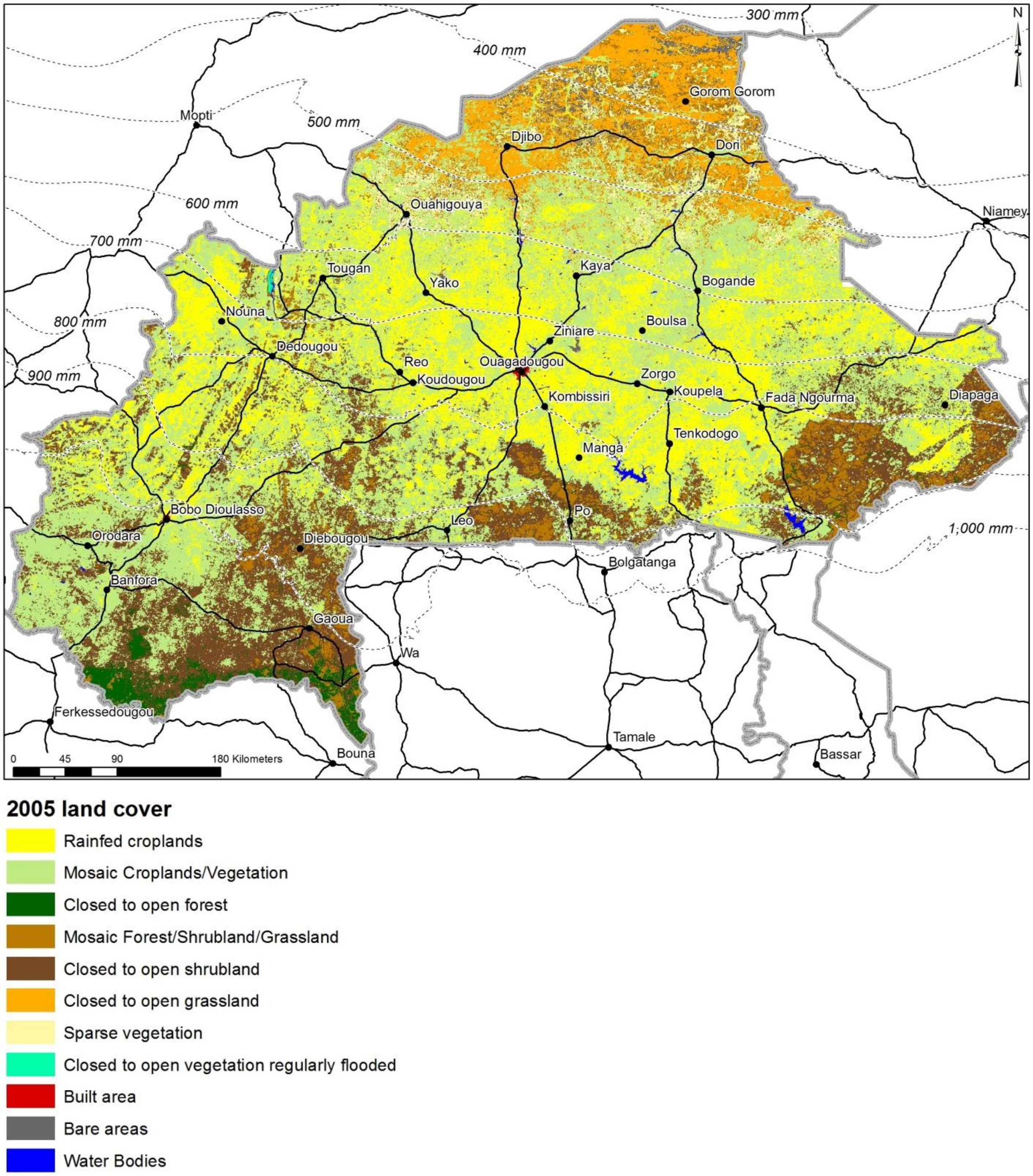
Over the last 30 years, Burkina's capacity to support agricultural production has been negatively impacted by land degradation. In the 1980s, the North was deemed to be the most degraded of Burkina (Kaboré and Reij 2004). Since then, despite major restoration projects, land degradation has spread. In 2002, 11% of the land was estimated to be very degraded and 34% moderately degraded (SP CONEDD 2006). In extreme cases, land degradation leads to the appearance and propagation of "zipellés", bare land with eroded, impermeable soils.

Land degradation results from the interaction of various factors, among which (adapted from SP CONEDD 2006):

- Demographic pressure: the quantity of arable land is not keeping up with a population growing at 2.5% a year, therefore decreasing the opportunity to regenerate cultivated lands through fallows. On the Central Plateau, for example, population density is high and fallowing land is no longer an option in most areas (see Map 2).

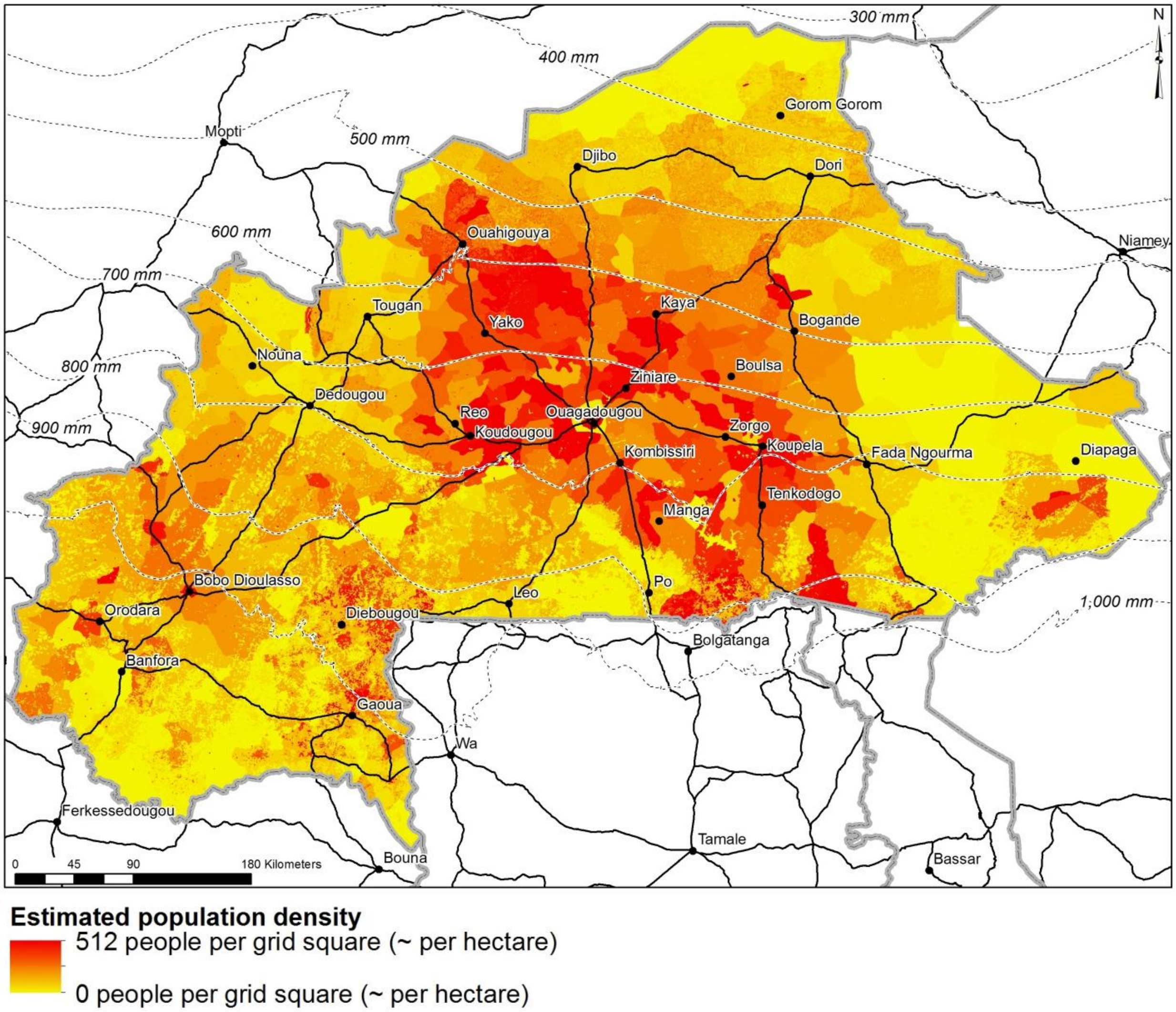
- Inappropriate legal and regulatory framework: property rights to land and trees are often not secure and ownership of forests is the hands of the state. Without clear rights to land and trees, farmers cannot fully secure the fruits of their investments in agroforestry, water harvesting and other forms of improved soil and water management.
- Agricultural policies and program priorities: agricultural intensification has promoted the use of inputs (e.g., mineral fertilizer) and mechanized cultivation (e.g., animal traction, tractors), while giving much less attention and support to boosting the intrinsic productivity of cropland through soil and water conservation, agroforestry and improved soil fertility management to increase and sustain agricultural production.
- Traditional cultural practices: farmers burn crop residues to clean the fields and increase soil fertility. Overgrazing by livestock is also on the rise as there is higher density of livestock on the reduced land areas available for use by (agro-)pastoralists.
- Climate change: As other countries of the Sudano-Sahelian region, Burkina Faso's agriculture is mainly rain-fed, making it vulnerable to the quantity of rainfall as well as its distribution in space and in time. Over the last 60 years, a migration of the isohyets to the South has been experienced (based on a comparison of data from FAO and Agrhymet 1986, and Hijmans et al. 2005), which translates into a decrease in rainfall, but during the last 10 – 15 years average rainfall has increased somewhat in parts of the West African Sahel, which means that the isohyets have crept northwards again (Nicholson 2013).

Map 1: Land cover in Burkina Faso, 2005



Sources: Land cover (FAO 2005), isohyets (Hijmans et al. 2005), international boundaries (FAO 2006), cities (ESRI 2013), and roads (ESRI 2013).

Map 2: Estimated population density in 2010



Sources: Estimated population density (WorldPop 2010), isohyets (Hijmans et al. 2005), international boundaries (FAO 2006), cities (ESRI 2013), and roads (ESRI 2013).

While conventional wisdom would categorize degraded lands, especially zipellés, as lands with low to no agricultural potential and predict their continuous expansion, observations on the ground are demonstrating that, with special care, these lands can be and are reclaimed to support farmers' livelihoods. With an increased density of trees in some landscapes, some parts of northern Burkina Faso are showing an agricultural revival (www.africa-regreening.blogspot.com; Reij et al. 2005).

This reversal in trajectory can be attributed to many different efforts by a multiplicity of actors, among others, the adaptability and innovativeness of farmers, the strengthening of land and tree tenure, and expansion of activities to support decentralized natural resource management and farmer innovation.

These efforts have slowed down the rate of land degradation by recovering tens of thousands of hectares of degraded land deemed lost to agricultural production. To have decisive gains in agricultural production and productivity at the national level, there is a need to accelerate and scale up the implementation of practices that have been adopted by farmers and proven effective in reclaiming degraded cropland and in boosting the agricultural productivity of the land.

Section 3 describes a few selected proven, cost-effective agricultural practices to restore the productivity of the land. Section 4 discusses the current uptake of these practices in the Central Plateau and assesses the potential for scaling them up at the national level based on readily available data[1] by assessing where each of these agricultural practices could be implemented and what their potential is in terms of agricultural production. Section 5 identifies the constraints to scaling up these practices as identified by local, regional and national actors already involved in the promotion of these practices. Section 6 sketches the way forward towards a national agroforestry strategy.

3. Improved soil and water management and agroforestry practices in the Northern Central Plateau: recent developments and current status

Description of selected proven practices

With little financial resources, the farmers have improved traditional soil and water conservation practices (e.g., zaï, contour stone bunds) and adopted other innovative techniques to restore the productivity of the land (e.g., using farmer managed natural regeneration to restore agroforestry systems).

Zaï

Zaï (or Improved Planting Pits) is a technique to recover bare, encrusted land through digging holes of 20-40 cm in diameter and 10-15 cm deep according to the type of soil. Organic matter (manure or compost) is added to the pit before planting time. After the first rainfall, the seeds (e.g., millet, sorghum or tree species) are placed in the middle of the pit (Figure 1).

[1] The results of this analysis are as good as the data used to produce it. For example, it is highly recommended to update the land cover data as it is believed to overestimate the cropland area.

Figure 1: Woman adding manure to her zaïs

Credit: M. Tall (CCAFS WA)

The advantages of zaï are (adapted from WB 2005 and Reij et al. 2009):

- It captures rainfall and run-off water, increasing water availability to the plant and reducing the negative impacts of erratic rainfall and periodic dry spells;
- It protects seeds and organic matter from being washed away;
- It concentrates nutrient and water availability near the planted seed at the beginning of the rainy season;
- It reactivates biological activities in the soil, which eventually leads to an improvement in soil structure and soil fertility; and
- It increases soil organic matter content and improves the uptake of mineral fertilizer by the plant.

As a result of its improved management of soils and water, zaï increases short and longer-term agricultural yields (Table 1). The unparalleled advantage of zaï is that it can be used to reclaim bare soils. This means that the land goes from producing 0 kg/ ha of sorghum per year to 300–400 kg/ha in a year of low rainfall, and 1,500 kg/ha in a good year (Kaboré and Reij 2004). The data also show that 2007 was a drought year and under these conditions the yield difference between the “with” and “without” situations was highest.

Table 1: Sorghum yields (kg/ ha) on farms with and without zaï, 2006-2008

	2006 359 mm rainfall during growing season		**2007** 336 mm rainfall during growing season		**2008** 449 mm rainfall during growing season	
	Kg/ ha	**% change**	**Kg/ ha**	**% change**	**Kg/ ha**	**% change**
Ouédraogo Noufou *(farm without zaï)*	436	N/A	319	N/A	642	N/A
Sawadogo Kassoum *(farm with zaï)*	1,200	+175	1,100	+245	1,600	+149
Ouédraogo Abdoulaye *(farm with zaï)*	975	+124	1,230	+286	1,508	+135
Sawadogo Moussa *(farm with zaï)*	1,312	+201	922	+189	1,456	+127

Source: Adapted from Sawadogo 2011

Although table 1 is about a very small sample of farmers, these findings corroborate the positive impacts of zaï on cereal yields estimated to vary between 40 percent to more than 100 percent from many other studies (see literature review in Reij et al. 2009 and research results reported in Winterbottom et al. 2013).

Contour stone bunds

Contour stone bunds are built along contours to slow down runoff water, reducing water erosion and increasing infiltration. The stones are anchored in furrows, which are usually a few centimeters deep. Their width is about 15-20 cm, and their length varies between 10-100 m (Figure 2).

Figure 2: Contour stone bunds and zaï

Credit: C. Reij

Contour stone bunds increase the availability of water to crops and this has a positive impact on crop yields (Table 2, Box 1). In case of very heavy rainfall, the yields may decline as part of the fields may be flooded temporarily. In such cases farmers remove a few stones, to let any excess water pass through.

Table 2: Sorghum yields (kg/ ha) on farms with and without contour stone bunds, 2006-2008

	2006 *359 mm rainfall during growing season*		**2007** *336 mm rainfall during growing season*		**2008** *449 mm rainfall during growing season*	
	Kg/ ha	**% change**	**Kg/ ha**	**% change**	**Kg/ ha**	**% change**
Ouedraogo Noufou *(farm without contour stone bunds)*	436	N/A	319	N/A	642	N/A
Sawadogo Kassoum *(farm with contour stone bunds)*	892	+105	723	+127	1,065	+66
Mande Abdoulaye *(farm with contour stone bunds)*	772	+77	819	+157	1,012	+58
Sawadogo Moussa *(farm with contour stone bunds)*	932	+114	856	+168	1,039	+62

Source: Adapted from Sawadogo 2011

The positive, statistically significant impact of stone bunds on average cereal yield reported by Sawadogo 2011 is consistent with the results from other studies that have reviewed the impact of these improved practices in many locations and over large areas (see literature review in Reij et al. 2009 and Winterbottom et al. 2013).

Farmers often combine more than one technique to create a synergistic effect (Kaboré and Reij 2004). For example, zaï and contour stone bunds used together produced higher cereal yields compared to the increase in yields obtained from use of a single technique (Table 3).

Table 3: Impact of improved soil and water management practices on cereal yields in 2007 (kg/ ha)

	Fields without improved soil and water management practices	**Fields with zaï**		**Fields with contour stone bunds**		**Fields with zaï and contour stone bunds**	
	Kg/ ha	**Kg/ ha**	**% change**	**Kg/ ha**	**% change**	**Kg/ ha**	**% change**
Ziga village	434	772	+78	574	+32	956	+120
Ranawa village	379	804	+112	531	+40	922	+143

Source: Adapted from Sawadogo 2011

Box 1: Voice from farmers - Mr. Harouna Ouédraogo, Ranawa Village

‘‘In 1980 only two families had cattle, now all families have cattle. Almost no one had a roof of corrugated iron and just look around you and you’ll notice that almost every family has such roofs. All our wells fell dry and for that reason girls from neighboring villages did not want to marry boys from our village. The land where we stand used to be barren, but now it has become productive again and all the trees that you see in these fields have grown since we started to construct contour stone bunds’’.

Source: Adapted from Reij et al. 2005.

Agroforestry

Agroforestry is defined as “a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence” (Lundgren and Raintree 1982). It includes measures that increase the density of trees on pastures and croplands, through tree planting, assisted natural regeneration, and farmer managed natural regeneration (FMNR). FMNR is an agroforestry technique of protecting and managing woody species which regenerate spontaneously on cultivated land (Figure 3). Often, woody species appear in land that used to be barren and degraded, but has been restored to productivity with the use of water harvesting techniques like zaï and contour stone bunds because farmers who invest in water harvesting techniques also invest in improved soil fertility management. The manure they add contains seeds of trees and bushes, which have been browsed by livestock. Like the crops, these seeds benefit from the concentration of water and fertility. If farmers decide to protect and manage the woody species, which emerge they create a new agroforestry system. Belemviré (2003) found that the density and the diversity of tree species on fields with water harvesting techniques are higher than on adjacent untreated fields.

The presence of trees on fields increases the availability of litter, which helps maintain or improve soil organic matter. This helps increase the water holding capacity of the soil. Trees and bushes also provide some shade to the crops thereby reducing evapotranspiration. Farmers implementing agroforestry are able to significantly increase on-farm tree densities. In a recent study of farmers in the village of Leba, the farmer who was not implementing agroforestry had less than 10 trees per hectare on his field while the three farmers who were implementing agroforestry had more than 30 trees per hectare (Table 4, based on calculations from Sawadogo 2011).

Figure 3: Farmer selectively pruning tree regrowth

Credit: C. Reij

Because agroforestry has been adopted more recently and is often implemented in combination with other improved soil and water management techniques, such as zaï and contour stone bunds, the evidence of its incremental added value in terms of agricultural production is often difficult to measure. In the Maradi and Zinder Regions of Niger, the yield increase was estimated at +100 kg/ha (Reij et al. 2009).

In addition to increasing crop yield, trees provide fodder for on-farm livestock. They also make firewood available, freeing women’s time, and supply families with nutritious and medicinal leaves or fruits. These non-timber forest products enable farmers to diversify their sources of income and food (Box 2). While there is no comprehensive data on the value of on-farm trees to Burkinabe farmers, a study conducted in the Maradi and Zinder Regions of Niger estimated the annual value of each tree at $1.40 (700 CFA) from improving soil fertility and having fodder, fruit, firewood and other produce available (Larwanou and Adam 2008). The average value of a tree will depend on the tree species and its age.

Table 4: Tree density on the "glacis"[2] on farms with and without agroforestry in the village of Leba, Burkina Faso

	Acacia spp.		***Sclerocarya birrea***		***Vitellaria paradoxum***		***Lannea microcarpa***	
	Number of trees/ ha	**% change**	**Number of trees**	**% change**	**Number of trees/ ha**	**% change**	**Number of trees/ ha**	**% change**
Ouédraogo Noufou *(farm without agroforestry)*	3	N/A	2	N/A	0	N/A	2	N/A
Sawadogo Kassoum *(farm with agroforestry)*	19	+533	13	+550	2		6	+200
Ouédraogo Abdoulaye *(farm with agroforestry)*	21	+600	9	+350	4		5	+150
Sawadogo Moussa *(farm with agroforestry)*	16	+433	17	+750	2		7	+250

Source: Adapted from Sawadogo 2011

Box 2: Voice from farmers - Mr. Seydou SAWADOGO, Saye Village

"The benefits I get from the application of agroforestry are primarily a source of satisfaction for myself. When I come here at any moment I'm very happy with the results I achieved. Then for my family, we managed to increase our agricultural yields per hectare. Before this technique on the same land we couldn't have more than 2 cartloads of millet a season. Today, with five cartloads of millet I can feed my family until the next harvest. Other reasons for satisfaction are that in my field there are plenty of fruit trees that attract birds and animals, but also and especially the students of the school nearby. Children come here to harvest berries from the jujube plant. I also see the advantage of the presence of trees in my field as they protect the crop, slowing the wind speed and torrential rains. The leaves are organic fertilizers for the soil. The canopy is attractive, the animals come regularly to graze, the added firewood benefits women for cooking. The benefits, we cannot mention them all."

Source: Adapted from Ouédraogo and Ouédraogo 2013.

[2] Glacis are gentle slopes situated between the plateau (high land) and the bas-fond (lowland). They are mostly used for agriculture (Niang 2004).

Socio-economic benefits

Increasing and diversifying agricultural yields through improved soil and water management practices and agroforestry significantly impacts the well-being of farmers. First, it increases and diversifies their source of food and income. Not only income sources are diversified at the family level but within the family, the women start to earn an income from selling woodfuel, leaves and fruits harvested from the trees, making them more financially independent.

There are also strong indications that the implementation of these improved practices has recharged groundwater locally, increasing the number of months with water in wells (Reij et al. 2009, Belemviré et al. 2008). In case of agroforestry, women also have a better access to wood fuel. Increased availability of water and wood fuel both significantly alleviate the daily burden of women who are responsible for collecting water and firewood.

Agroforestry and improved soil and water management practices enhance farmers' food, water and energy security and they sustainably restore the capacity of agricultural land to support livelihoods.

The increased capacity to support people has implications for rural-urban migration. With brighter perspectives at home, young men as well as entire farm families decide to stay in the village rather than migrate to the city or settle in other regions.

At an individual level, farmers who have innovated have gained social status as persons of knowledge. Last but not least, as expressed by Mr. Seydou Sawadogo (Box 2), farmers have now in their land a source of pride.

In the context of a changing climate and high population growth, the adoption of improved soil and water management practices and agroforestry enables farmers to replenish their natural capital while benefiting from it. These practices both help farmers to adapt to climate change by increasing the water availability to their crops and help to mitigate climate change by sequestering carbon in on-farm woody species.

While there is growing evidence of the added value of implementing agroforestry and improved soil and water management practices on food, energy and water security, these practices are not reaching all the farming families who could increase their well-being by implementing these improved practices. Up until now, these practices have been spreading mostly in specific areas. To accelerate the scaling of these practices in regions with favorable conditions, there is a need for the Government to step in through setting supportive legal frameworks and incentives. The next section will discuss what has been already achieved, how much more could be achieved, and ways forward to scale up.

4. From here to there: current uptake and discussion for scaling up

Current uptake in the Central Plateau

Reij et al. (2009) mention that by 2009 an estimated 200,000 to 300,000 hectares had been restored to productivity through zaï and/ or contour stone bunds practices on the Central Plateau of Burkina. Most recovered land was bare and encrusted, and producing no crops at all (Ouédraogo 2005). Thanks to the zaï and contour stone bunds, crop yields could rise to 300-400 kg/ ha in a year with low precipitation and possibly to 1,500 kg/ ha in a year with good precipitation (Reij et al. 2009). Reij et al. assess that an additional 80,000 tons is harvested a year, using a conservative net average gain in cereal yield of 400 kg/ ha over 200,000 hectares.

Opportunities for scaling up

One of the questions to answer regarding scaling up is where would these improved land management practices most improve families' livelihoods. Using available spatial data, we identified the number of hectares most promising for implementation of zaï, contour stone bunds, and agroforestry, and assessed what it would mean in terms of change in livelihoods for the farming families. While these analyses are only preliminary, they can already provide a basis for discussion.

Method

To assess land suitability to zaï, contour stone bunds, and agroforestry, four factors were taken into consideration: soil characteristics, rainfall, land cover, population density. Land form/ lithology was also considered for contour stone bunds as this practice requires stones, which need to be locally sourced for it to be economically feasible.

Soil characteristics

Based on their observations in Northern, Central-North, Central-West, and Central Plateau, Burkinabe experts first identified five soil characteristics that determine the suitability of a given soil for implementing zaï, contour stone bunds, and agroforestry: soil texture, soil drainage, inherent soil fertility, soil depth and generalized landform. Then they assigned, for each soil and water management practice, a suitability rating to different states of each of these characteristics: 3 – high suitability, 2 – medium suitability, 1 – low suitability, and 0 – not suitable. Tables 5-9 display these ratings.

Table 5: Soil texture and improved land management practices suitability

Soil texture class	Zaï	Contour stone bunds	Agroforestry
Sand	0	0	3
Gravel	3	3	3
Clay	1	1	1
Silt	1	2	2
Hardpan	3	3	1
Silty clay and clayey gravel	3	3	2

Legend: 0 – not suitable, 1- low suitability, 2- moderate suitability, 3- high suitability

Table 6: Drainage and improved land management practices suitability

Drainage class	Zaï	Contour stone bunds	Agroforestry
Slightly to very excessive drainage	0	1	0
Good drainage	1	2	2
Moderate drainage	3	3	3
Imperfect drainage	3	3	3
Poor to very poor drainage	3	1	3

Legend: 0 – not suitable, 1- low suitability, 2- moderate suitability, 3- high suitability

Table 7: Inherent soil fertility and improved land management practices suitability

Soil fertility class	Zaï	Contour stone bunds	Agroforestry
Low	3	3	3
Moderate	2	2	2
High	1	1	1

Legend: 0 – not suitable, 1- low suitability, 2- moderate suitability, 3- high suitability

Table 8: Soil depth and improved land management practices suitability

Soil depth class	Zaï	Contour stone bunds	Agroforestry
Deep (>100cm)	0	0	3
Moderate (40 - 100 cm)	2	2	3
Shallow (<40 cm)	3	3	3

Legend: 0 – not suitable, 1- low suitability, 2- moderate suitability, 3- high suitability

Table 9: Landform and improved land management practices suitability

	Zaï	Contour stone bunds	Agroforestry
Low land	0	0	2
Glacis	3	3	3
High land	3	3	3

Legend: 0 – not suitable, 1- low suitability, 2- moderate suitability, 3- high suitability

Then, we used the 1:500,000 ORSTOM Soil Resource map[3] to assign a suitability rating to each soil unit. The full list of soil units and their individual suitability assignment can be found in Appendix 1 (it should be noted that soil suitability to zaï and contour stone bunds were assessed to be the same). It should be noted that some ratings were reviewed North of Djibo and Dori as the Burkinabe experts disagreed with

[3] Given the small scale of the soil map, soil inclusions are included in most map units. Additionally, rock outcrops, permanent water bodies, and/or highly saline/sodic soils, may be found within some map units and would obviously not be suitable for cropping. The suitability assignments should be seen as a generalized planning tool and should be further investigated at larger map scales in consideration of applying the recommendations. Nevertheless, the suitability by soil map unit/land practice offers a reasonably good place to begin in the process of encouraging local adoption of soil and water conservation practices.

the original classification of suitability to zaï, contour stone bunds and agroforestry based on soil characteristics. They assessed that there was no potential for zaï or contour stone bunds North of Djibo and Dori, and therefore all the area was assigned a "not suitable" rating. Regarding agroforestry, they assessed that there was some moderate suitability North of Djibo and Dori and it was low North of Gorom.

<u>Rainfall</u>

While agroforestry is not negatively affected by high rainfall, crops under zaï and contour stone bunds are. Since both slow down water runoff, their implementation in areas with too much rain could lead to drowning the crops whose yield they are meant to boost.

The upper limit of rainfall for zaï and contour stone bunds are 800 mm and 900 mm per year respectively (Roose et al. 1993, see Table 10).

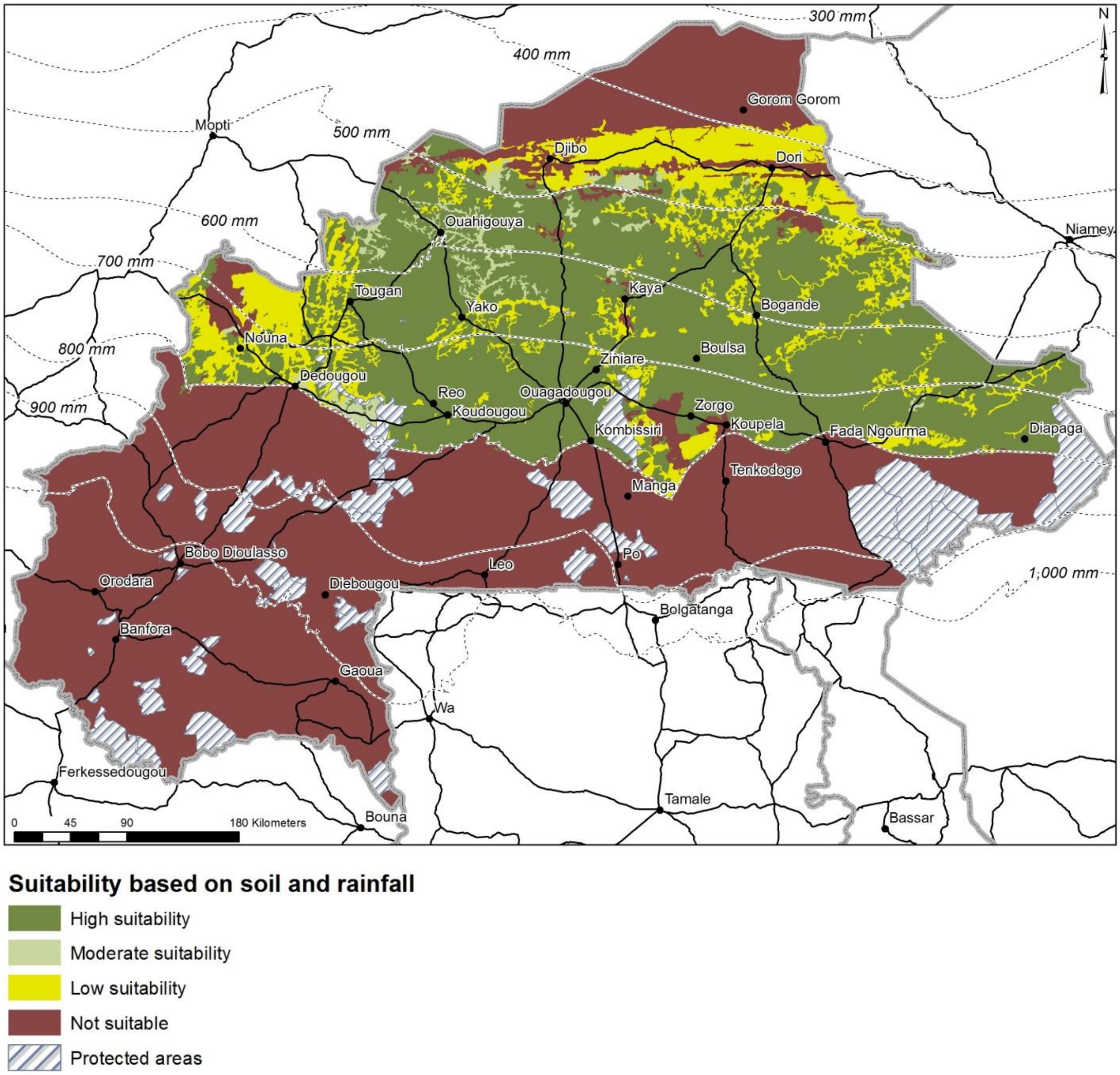
Table 10: Average annual rainfall and improved land management practices suitability

Rainfall (mm)	Zaï	Contour stone bunds	Agroforestry
301-400	1	1	1
401-500	1	1	1
501-600	1	1	1
601-700	1	1	1
701-800	1	1	1
801-900	0	1	1
901-1,000	0	0	1
> 1,000	0	0	1

Legend: 0 – not suitable, 1- suitable.

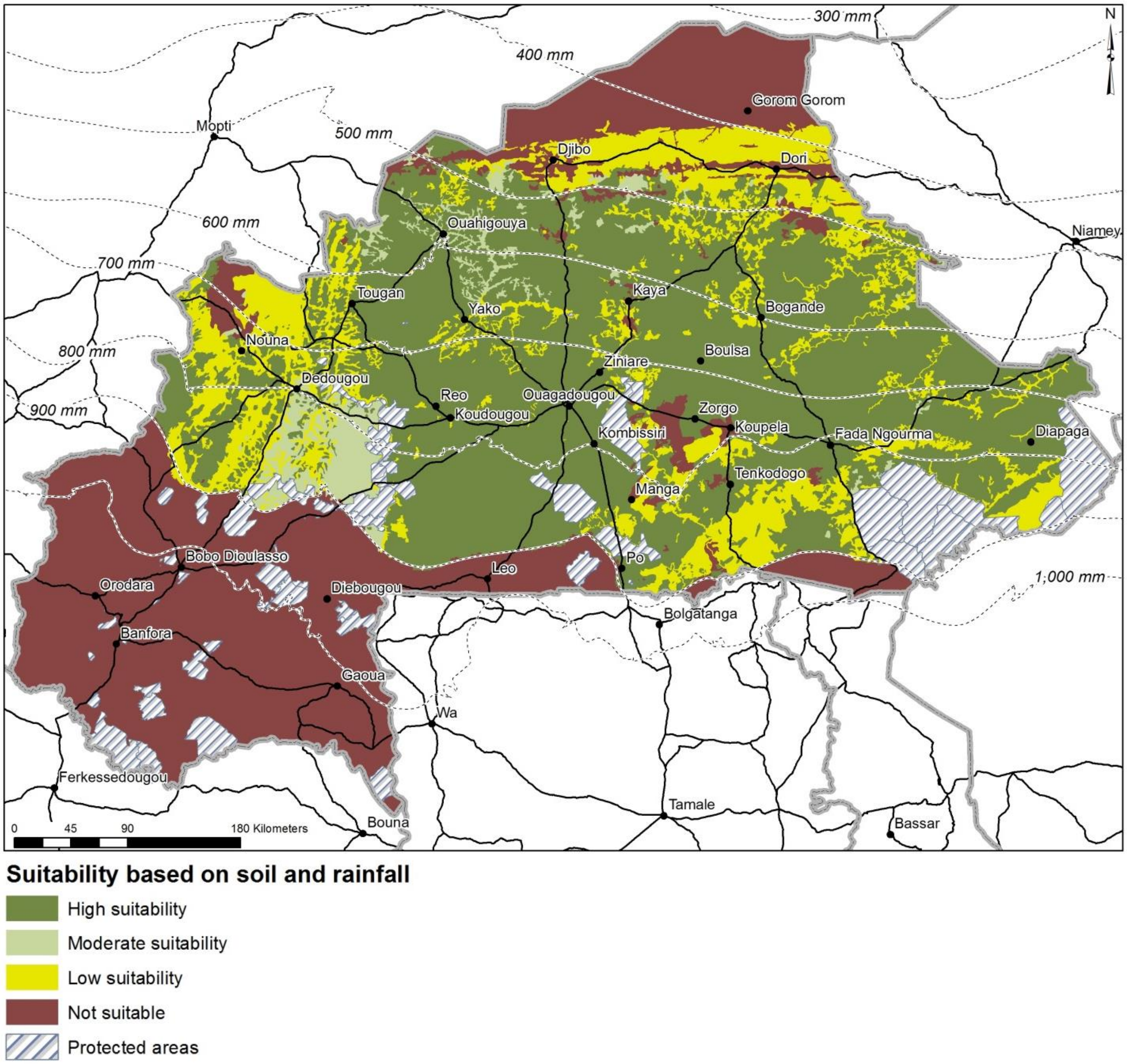
Maps 3, 4 and 5 present the suitability of land for zaï, contour stone bunds, and agroforestry respectively, based on its soil characteristics and average rainfall.

Map 3: Land suitability for zaï based on soil and rainfall



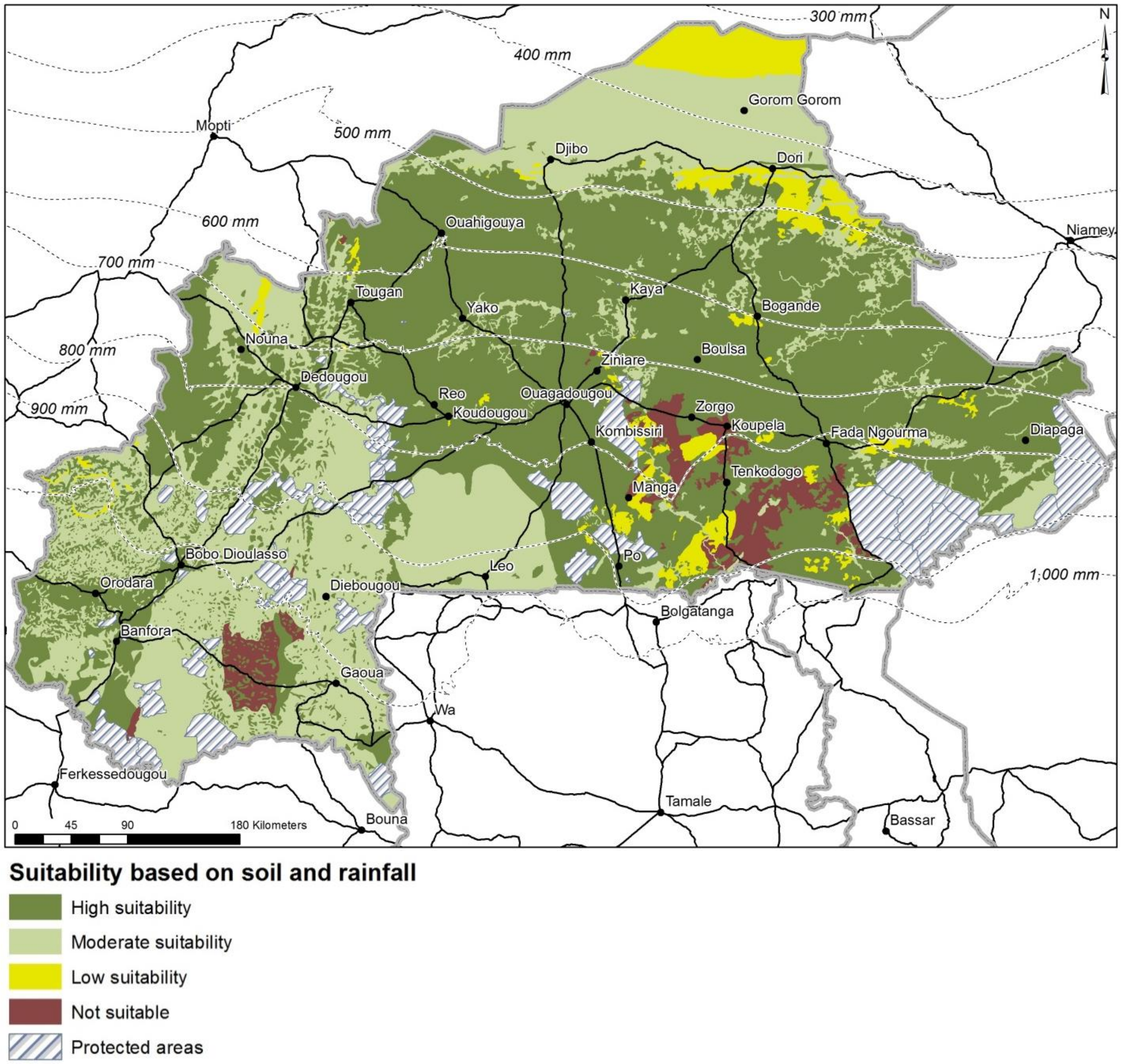
Sources: Suitability (calculations based on ORSTOM 1968 and Hijmans et al. 2005), isohyets (Hijmans et al. 2005), protected areas (Agrhymet undated), international boundaries (FAO 2006), cities (ESRI 2013), and roads (ESRI 2013).

Map 4: Land suitability for contour stone bunds based on soil and rainfall



Sources: Suitability (calculations based on ORSTOM 1968 and Hijmans et al. 2005), isohyets (Hijmans et al. 2005), protected areas (Agrhymet undated), international boundaries (FAO 2006), cities (ESRI 2013), and roads (ESRI 2013).

Map 5: Land suitability for agroforestry based on soil and rainfall



Sources: Suitability (calculations based on ORSTOM 1968 and Hijmans et al. 2005), isohyets (Hijmans et al. 2005), protected areas (Agrhymet undated), international boundaries (FAO 2006), cities (ESRI 2013), and roads (ESRI 2013).

<u>Land cover</u>

In addition to soil and rainfall, land cover is an important factor in identifying potential areas suitable for the implementation of zaï, contour stone bunds and agroforestry. For example, if there is already a relatively high density of woody biomass in an area of shrubland and forest, these areas are not considered as suitable for scaling up agroforestry, even if the soil characteristics and rainfall are suitable.

We used the 2005 land cover data at 300 meter resolution from the Global Land Cover dataset and assigned them a suitability rating (Table 11).

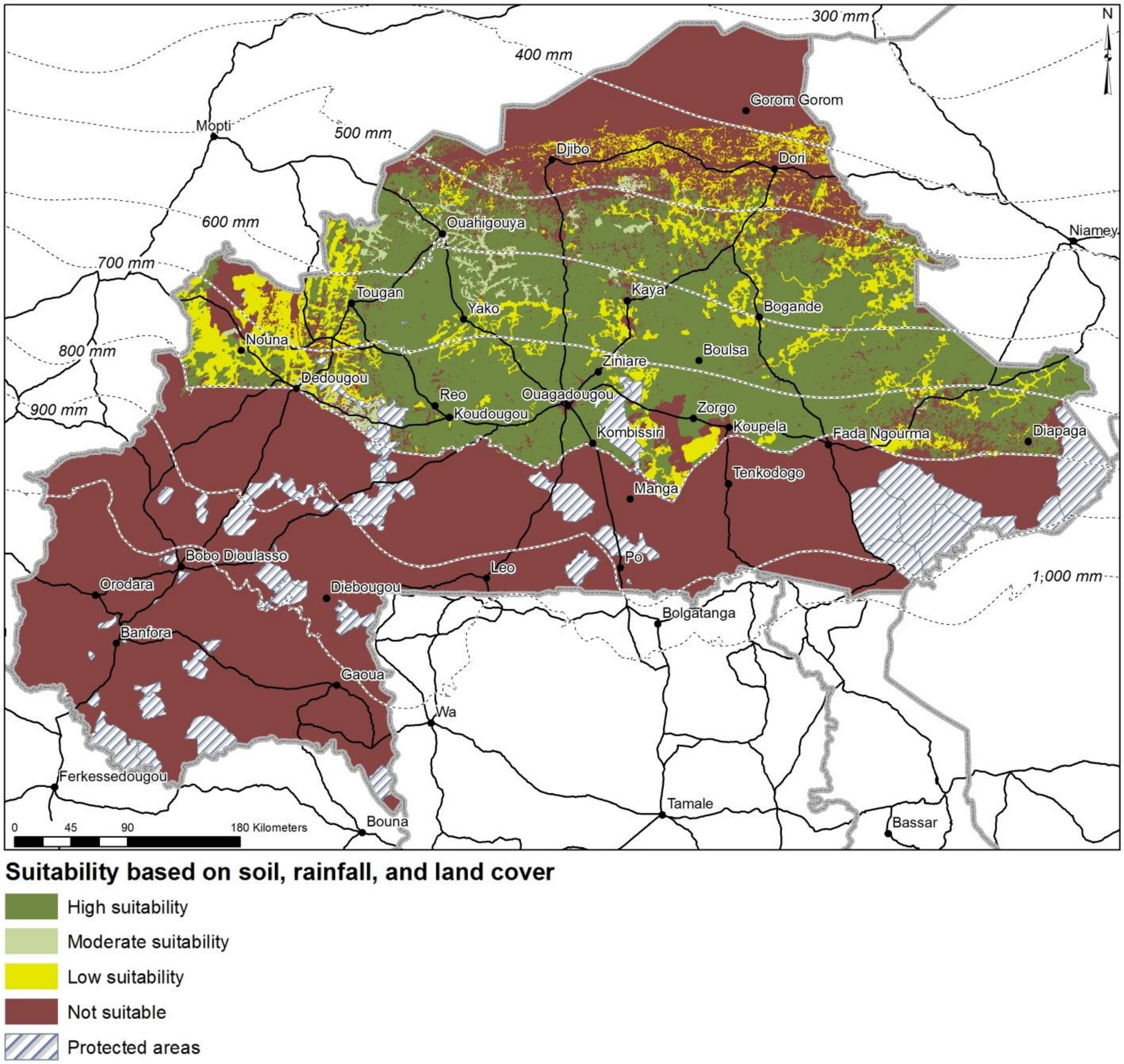
Table 11: Land cover and improved land management practices suitability

Land Cover classes	Gridcode	Area (ha)	Zaï	Contour stone bunds	Agroforestry
Rainfed croplands	14	6,011,445	1	1	1
Mosaic croplands/ vegetation	20, 30	11,900,670	1	1	1
Closed to open forest	40, 60	458,737	0	0	0
Mosaic forest/ shrubland/ grassland	110, 120	1,884,615	0	0	0
Closed to open shrubland	130	4,132,538	0	0	0
Closed to open grassland	140, 143	1,672,219	0	0	1
Sparse vegetation	150	891,157	1	1	1
Close to open vegetation regularly flooded	180	9,200	0	0	0
Built area	190	15,382	0	0	0
Bare areas	200, 201, 202	318,586	1	0	1
Water bodies	210	61,900	0	0	0
	Total area	27,356,449			

Legend: 0 – not suitable, 1- suitable.

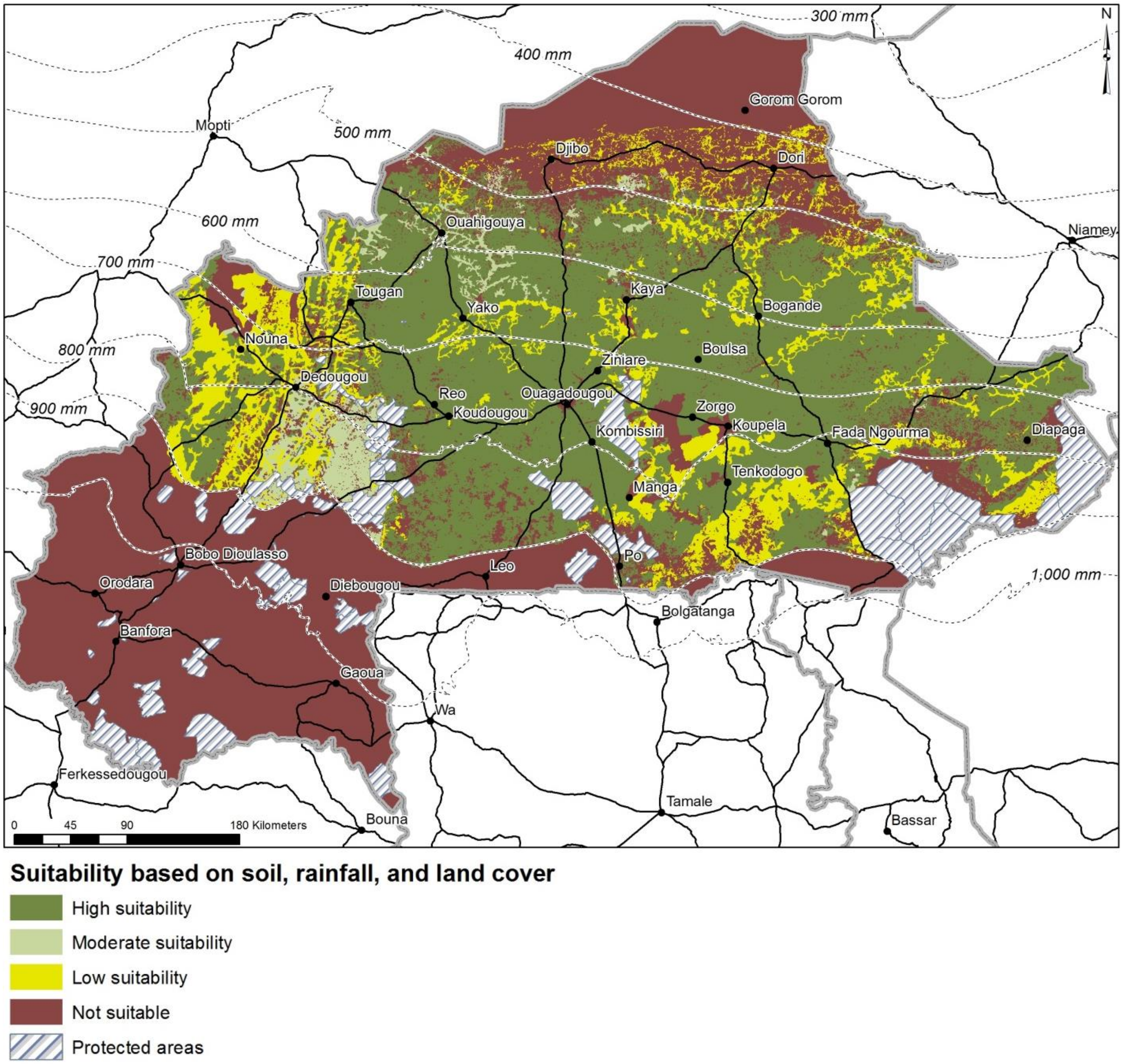
Maps 6, 7, 8 present the suitability of land for zaï, contour stone bunds, and agroforestry respectively, based on its soil characteristics, average rainfall, and land cover.

Map 6: Land suitability for zaï based on soil, rainfall and land cover



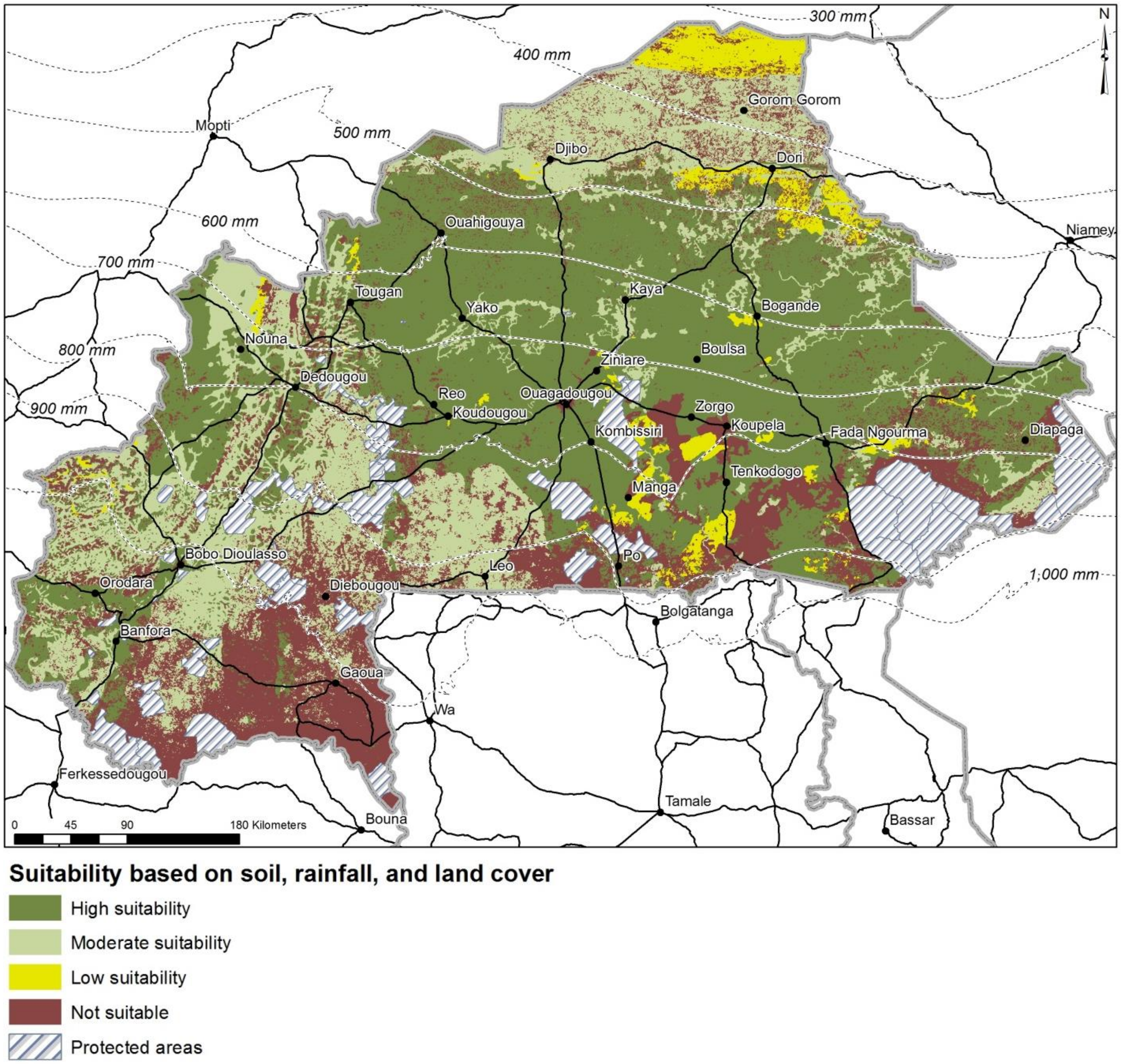
Sources: Suitability (calculations based on ORSTOM 1968, Hijmans et al. 2005, and FAO 2005), isohyets (Hijmans et al. 2005), protected areas (Agrhymet undated), international boundaries (FAO 2006), cities (ESRI 2013), and roads (ESRI 2013).

Map 7: Land suitability for contour stone bunds based on soil, rainfall and land cover



Sources: Suitability (calculations based on ORSTOM 1968, Hijmans et al. 2005, and FAO 2005), isohyets (Hijmans et al. 2005), protected areas (Agrhymet undated), international boundaries (FAO 2006), cities (ESRI 2013), and roads (ESRI 2013).

Map 8: Land suitability for agroforestry based on soil, rainfall and land cover



Sources: Suitability (calculations based on ORSTOM 1968, Hijmans et al. 2005, and FAO 2005), isohyets (Hijmans et al. 2005), protected areas (Agrhymet undated), international boundaries (FAO 2006), cities (ESRI 2013), and roads (ESRI 2013).

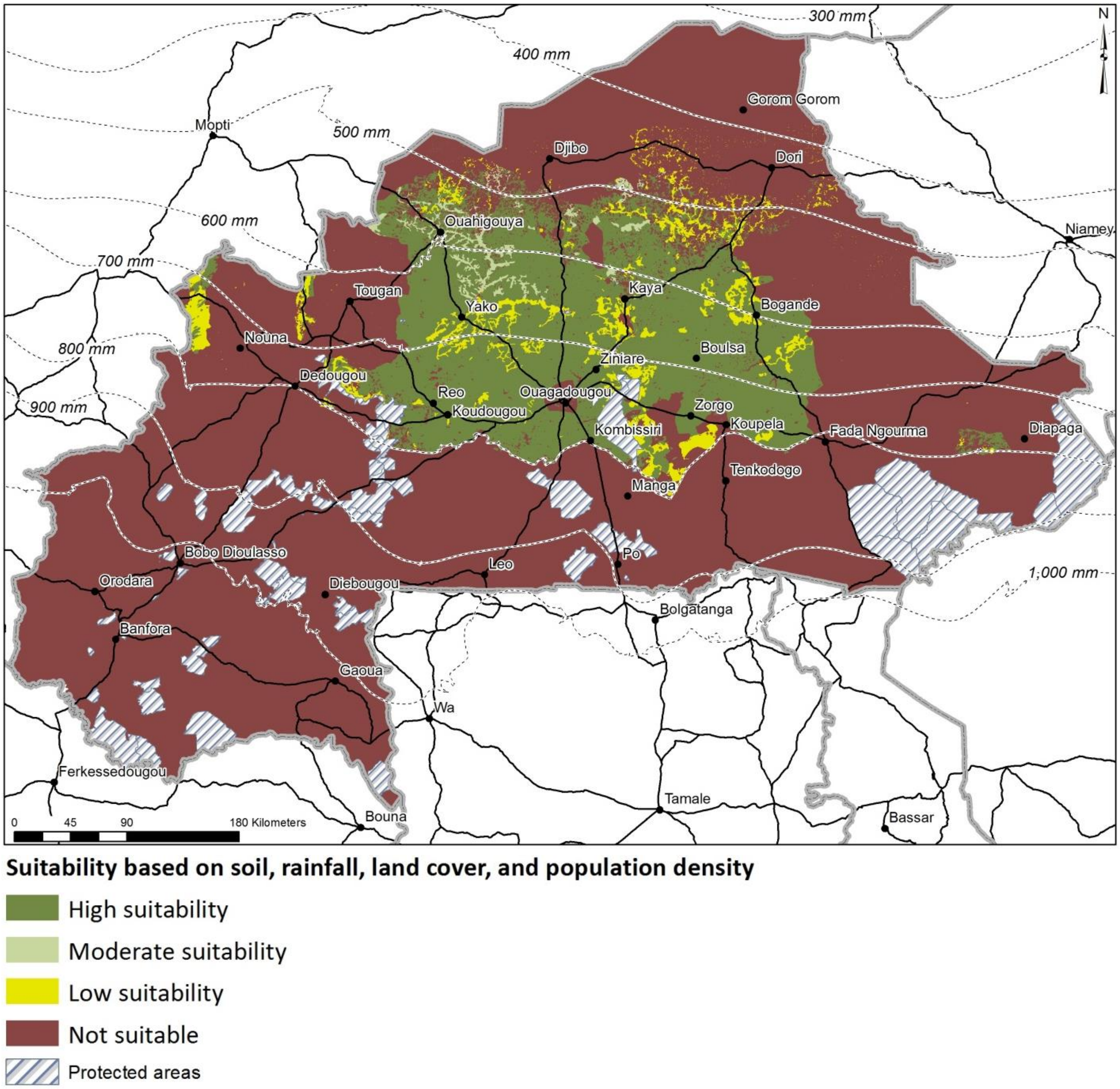
<u>Population density</u>

High population density encourages farmers to be more innovative in addressing constraints on agricultural production (Mazzucato and Niemeijer 2001). There is anecdotal evidence that thirty people per square kilometer is the lower limit of population density that tends to foster the spread of improved soil and water management practices, as above this density, people cannot easily move to another plot when their land becomes less productive.

We used the population density at 0.00833 degree resolution (about 100 m x 100 m at the Equator) of WorldPop and we assigned “not suitable” to areas with less than 0.3 people per square grid.

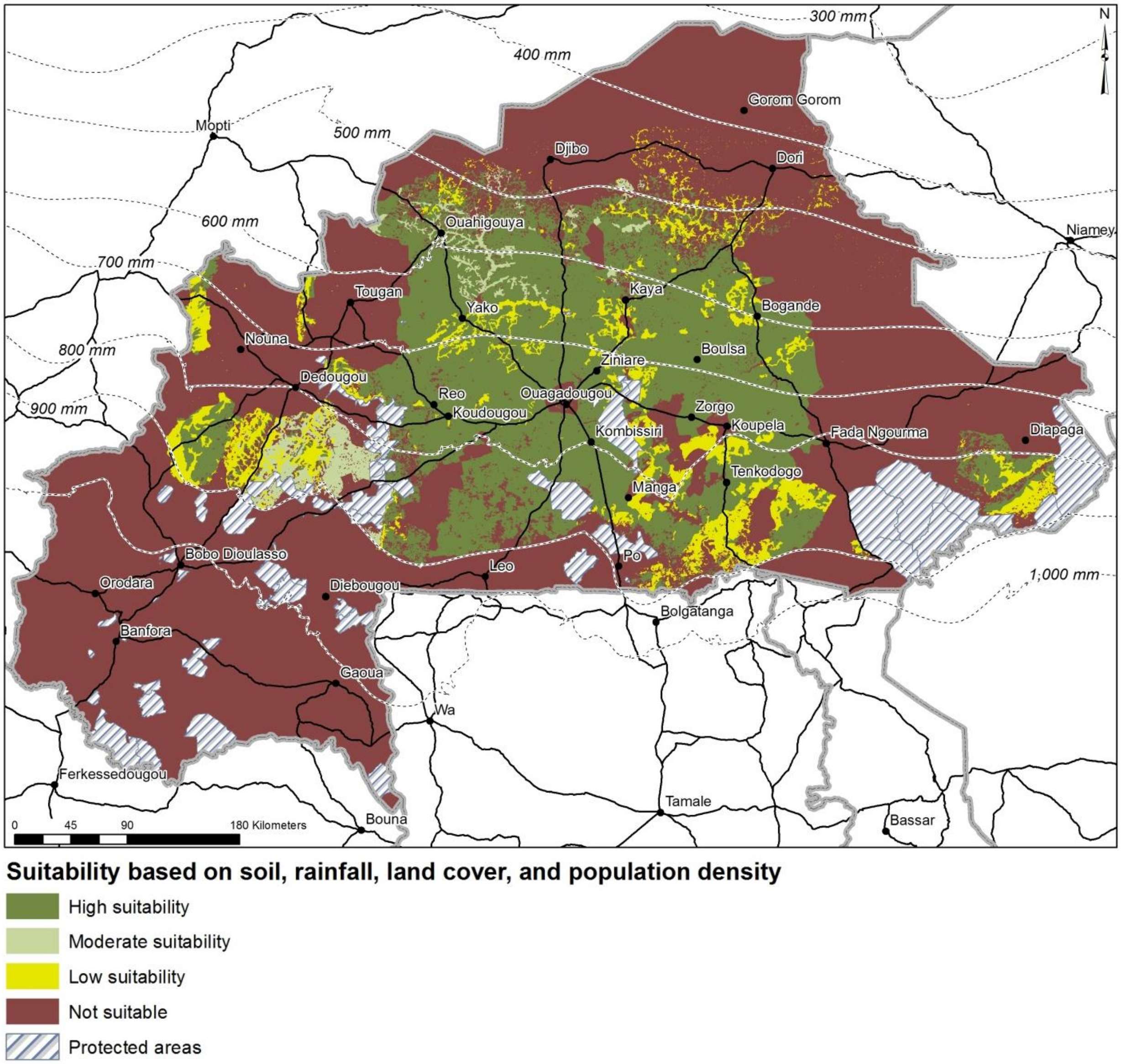
Maps 9, 10 and 11 present the suitability of land for zaï, contour stone bunds, and agroforestry respectively, based on its soil characteristics, average rainfall, land cover, and population density.

Map 9: Land suitability for zaï based on soil, rainfall, land cover, and population density



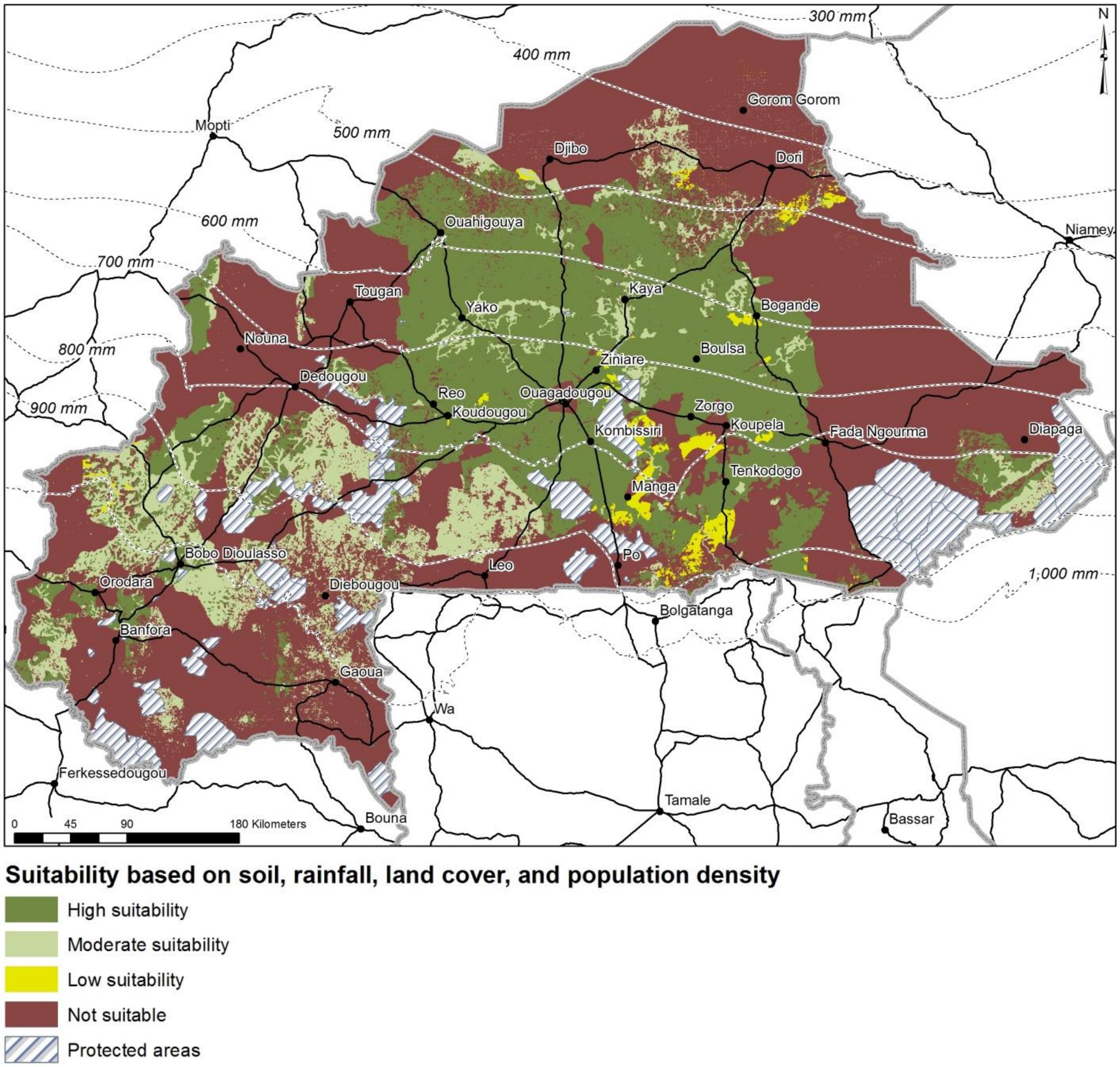
Sources: Suitability (calculations based on ORSTOM 1968, Hijmans et al. 2005, FAO 2005, and WorldPop 2010), isohyets (Hijmans et al. 2005), protected areas (Agrhymet undated), international boundaries (FAO 2006), cities (ESRI 2013), and roads (ESRI 2013).

Map 10: Land suitability for contour stone bunds based on soil, rainfall, land cover, and population density



Sources: Suitability (calculations based on ORSTOM 1968, Hijmans et al. 2005, FAO 2005, and WorldPop 2010), isohyets (Hijmans et al. 2005), protected areas (Agrhymet undated), cities (ESRI 2013), and roads (ESRI 2013).

Map 11: Land suitability for agroforestry based on soil, rainfall, land cover, and population density



Sources: Suitability (calculations based on ORSTOM 1968, Hijmans et al. 2005, FAO 2005, and WorldPop 2010), isohyets (Hijmans et al. 2005), protected areas (Agrhymet undated), international boundaries (FAO 2006), international boundaries (FAO 2006), cities (ESRI 2013), and roads (ESRI 2013).

Lithology

The availability of stones within 5 kilometers of the field where farmers aim to build contour stone bunds is a pre-requisite otherwise it is not economically feasible. Unfortunately, we could not find data regarding the lithology, and have therefore not tried to identify areas suitable for contour stone bunds.

Maximum potential area and agricultural production estimates

Because the intent is not to scale up improved agricultural practices within protected areas, we calculated the area of land highly suitable for each of the following practices outside of protected areas. Here are the preliminary estimates:

<u>Zaï</u>

- Area highly suitable to zaï: **4,900,000 hectares**
- Estimated maximum potential increase in production: **1.5-2 million tons** under the assumption that zaï brings an average of 300-400 kg/ ha over the 5,000,000 hectares

<u>Contour Stone Bunds</u>

Unavailable as a result of a lack of information on lithology. In many villages on the northern part of the Central Plateau with high population densities and access to stones, the stones have already been used for the construction of contour bunds or for marking plot boundaries. In some of the hilly areas between Kaya and Ouahigouya, there still is a potential for expansion.

<u>Agroforestry</u>

- Area highly suitable to agroforestry: **7,500,000 hectares**
- Estimated maximum potential increase in production: **750,000 tons** under the assumption that agroforestry brings an average of 100 kg/ ha over the 7,500,000 hectares

The total area of cropland where farmers have already adopted these improved practices has not been recently assessed, but the area treated with zaï and/or contour stone bunds was estimated to be around 250,000 ha in 2009 (Reij et al. 2009). So the estimated totals of land which is highly suitable for these practices most likely represents a ten-fold increase over the area where farmers now use these improved practices.

Constraints and barriers

Identifying highly suitable areas for scaling up agroforestry and improved soil and water management practices reveals the potential scope for increasing crop yields and farmers' well-being. While this is a useful first step, it is not sufficient, however, to just map and locate these lands with high potential; concerted efforts are also needed to address critical barriers to scaling up improved land management practices. This section summarizes the main constraints and barriers identified by farmer innovators (Réseau MARP-Burkina 2013a, Ouédraogo and Ouédraogo 2013) and the discussions that took place during a workshop conducted in March 2013 in Ouagadougou, which was attended by 50 participants, including farmer innovators, government officials, researchers and NGOs.

The challenge most repeatedly identified is that farmers are vulnerable to the usurpation of the fruits of their investment as a result of a weak natural resource rights framework (Box 3). Indeed, land tenure insecurity is a daily challenge for not all farmers who implement improved soil and water management practices have property rights to the land or the trees they have been caring for over the years, and sometimes over decades. As a result of weak property rights, the land can be taken away from the producer or the field is considered as grazing land open to all with livestock endangering the survival of young regenerated trees. While there is no data on the subject in Burkina Faso, anecdotal evidence and discussions at the workshop both point to the fact that farmers with secure tenure are more likely to make investments in improved land management.

Box 3: Voice from farmers – Mr. Michel KONKOBO, Songnaaba Village

"A company came to tell me it bought our land from the government. It cut down many fruit trees, trees that I had introduced, claiming that it had purchased the land".

Source: Adapted from Réseau MARP-Burkina 2013b

While most improved soil and water management practices boost crop yields soon after being implemented, farmers don't always have the labor to implement techniques such as zaï and contour stone bunds. For example, digging zaï usually requires between 300-650 hours per hectare according to soil condition and farmers' practice (Reij et al. 2009). The poorest farmers, who are actually the most likely to need labor-intensive management practices, are not necessarily unable to bring their land back to production, but they can only do so progressively. Richer farmers tend to have more family labor and are able to hire farm labor specialized in digging zaï. In addition, in many villages on the Central Plateau, stones have become scarce and it is uneconomic to transport them over a distance of more than five kilometers. Poor farm households don't have donkey carts for transport, which means that they depend on external support (project interventions) for the transport of stones. The evidence from Niger points to poor farm households having higher on-farm tree densities than rich farm households (Yamba and Sambo 2012). The explanation may be that poor households depend more on their natural resources than rich households.

Land tenure also has an impact on farm household investment decisions. A farmer who has borrowed his land and does for that reason not have permanent land use rights, is not allowed to plant trees, because planting trees is regarded an act of appropriation. He can protect and manage natural regeneration and sow tree seeds as this is an act different from planting. A farmer who has borrowed land temporarily will not invest in the construction of stone bunds or the digging of zaï.

Married women receive a plot of land from their husbands, but the quality of these plots tends to be marginal. Women do invest in zaï and stone bunds, but they run the risk that their husbands claim back the improved plots.

Last but not least, farmer innovators can be quite lonely in their undertaking. While there is more and more evidence of the impacts of agroforestry and improved soil and water management practices on farmers' livelihoods in Burkina Faso and in the wider region, it is not easy to have them documented so that farmers, government and civil society organizations know about how these successes came to happen. While this situation is slowly changing as more evidence is collected and disseminated, there is a need to understand the potential of this movement spearheaded from the ground by farmer innovators to act at the national level in support of scaling up these efforts.

Recommendations from the field

This section summarizes the recommendations discussed about scaling up agroforestry and other improved soil and water management practices during the workshop organized by Réseau MARP in March 2013 and present the tangible next steps agreed by workshop participants. While the solutions discussed were focused on agroforestry, they are relevant to scaling up other improved land management practices as caring for trees embodies the challenges of local farmers regarding investing in the land. Furthermore, farmers are likely to combine agroforestry with soil and water conservation and other improved land management practices to maximize the benefits of these practices.[4]

The following recommendations identified by farmer innovators, government representatives, and civil society organizations mirror the three types of constraints presented in the previous section (adapted from Réseau MARP-Burkina 2013a):

Provide a supportive policy and legal framework with clear property rights to foster implementation of agroforestry and improved soil and water management practices

- Incorporate considerations of soil and water management practices in existing national, provincial, local and sectorial policies, plans and strategies based on inputs from actors already engaged in the promotion of improved soil and water management practices.
- Establish a national agroforestry strategy that provides clear property rights to trees outside forests so that farmers are more inclined to invest in and care for trees in their fields.

Provide financial support to farmers implementing agroforestry and improved soil and water management practices

- Establish a fund to support the implementation of improved land management practices.
- Facilitate farmers obtaining loans for implementation of improved land management practices from microcredit or financial institutions.
- Establish other financial incentives to encourage farmers to implement agroforestry and soil and water management practices (such as subsidies or tax credits).

Foster a community of practice and build the capacity of farmers, government and civil society groups

- Regularly review the uptake of improved soil and water management practices (areas, species used, ecological impacts (e.g., biodiversity, soil fertility), socio-economic impacts (e.g., income, food security, women's burden for fetching water and wood), and adaptation to climate change (e.g., crop yields under different rainfall conditions, changes in surface and groundwater hydrology).
- Organize farmer-to-farmer visits in the presence of the local and regional government authorities and civil society groups.

[4] See Winterbottom et al. 2013, for evidence of the benefits of combining improved land and water management practices.

At the workshop, the attendants unanimously decided to start the process of scaling up improved soil and water management and agroforestry practices in Burkina Faso. They pledged to work together and define and implement a national agroforestry strategy. More specifically, they proposed the following 6 steps:

1. Put a technical committee in place for the elaboration of a national agroforestry strategy;
2. Lobby the relevant authorities for the launch of a process to establish a national agroforestry strategy;
3. Engage stakeholders around the establishment of a national agroforestry strategy;
4. Organize an awareness and discussion workshop on a national agroforestry strategy;
5. Organize a validation workshop of the a national agroforestry strategy;
6. Shepherd the national agroforestry strategy through the adoption process by the Government of Burkina Faso.

5. Conclusion

Using readily available data, this Working Paper identified areas of high potential regarding the implementation of zaï and agroforestry. As more updated and detailed data become available, improved maps and statistics can be produced.

Beyond providing preliminary maps and statistics related to the potential for scaling up these improved land management practices in Burkina Faso, this paper also presents a method to target areas to scale up agroforestry and improved soil and water management practices based on ecological and social criteria. While it was developed for Burkina Faso, the method could easily be adapted to other countries where land restoration efforts are being planned.

We hope this Working Paper will contribute to the ongoing scaling up efforts such as the DGIS funded Regional Program in the Sahel and Horn of Africa of “Enhancing Food and Water Security for Rural Economic Development” led by the World Agroforestry Center, the USAID funded Resilience program being implemented in Burkina Faso and Niger, the GEF and World Bank funded Great Green Wall initiative and related investment programs.

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Appendix 1: 1:500,000 soil classes and improved land management practices suitability

Soil class	Zai/ contour stone bunds suitability	Agroforestry suitability
1	0	2
1a	1	3
1b	1	3
1c	2	3
1d	1	2
2	0	2
2a	0	2
2b	0	2
2c	0	2
3	0	3
4	0	3
4a	0	3
5	1	1
5a	1	1
5b	1	1
5c	0	1
6	1	1
6a	1	1
7	2	3
7a	0	1
8	3	3
8a	3	3
8b	3	3
8d	3	3
8f	3	3
8g	3	3
8h	3	3
8i	3	3
8j	3	3
8k	3	3
8m	3	3
9	1	2
9a	1	2
9b	1	2

Soil class	Zai/ contour stone bunds suitability	Agroforestry suitability
9c	1	2
9d	1	2
9e	1	1
9f	1	2
9g	1	1
9i	1	1
9j	1	2
9k	1	2
9m	1	2
9q	1	3
10	1	1
10a	3	3
10b	1	2
10c	1	1
10d	1	1
10e	0	0
10f	1	1
10g	2	2
11	0	0
11a	1	0
11b	0	0
11c	0	0
11d	0	0
11e	0	0
12	1	2
12a	3	3
12b	3	3
12c	3	3
12d	1	2
12e	1	2
12f	1	1
12g	1	1
12h	1	2
12i	1	2

Soil class	Zai/ contour stone bunds suitability	Agroforestry suitability
12j	2	2
12k	1	2
12m	1	2
12n	1	2
12p	1	2
12q	1	2
12r	1	2
12s	1	2
13	3	3
13a	1	3
14	1	3
14a	3	3
14b	3	3
14c	3	3
14d	3	3
14e	2	2
14f	1	3
14g	3	3
14i	2	3
14j	2	3
14k	2	2
14l	0	2
14m	0	0
14n	0	0
14p	1	2
14q	0	2
15a	3	3
15b	3	3
15c	3	3
15d	3	3
15e	3	3
15f	3	3
15g	3	3