

### H-3 Fragility of the Sahelian Farmers and Soil Degradation: A Consideration of Policy Intervention

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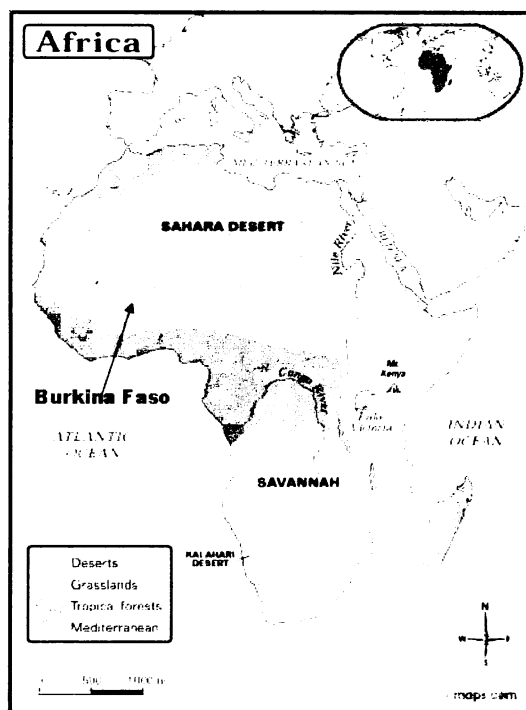
#### 1. Introduction

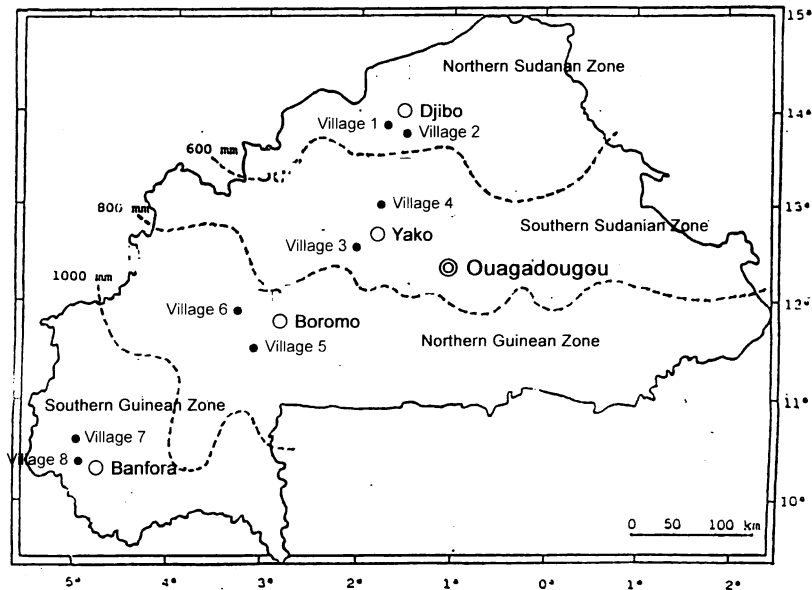
It is often pointed out that there is a vicious cycle between the degradation of natural resources and poverty. However, it is not yet obvious if the prevention of desertification, which is one of the most important issues in global environment research, really has an impact on poverty alleviation, and if poor farmers in fact accelerate soil degradation. Hence, this research project aims to investigate empirically the relationship between the degradation of natural resources and the poverty, and then to make policy recommendations. For this purpose, we selected Burkina Faso, a landlocked country in West Africa, as our study site.

Burkina Faso is located on the southern edge of the Sahara desert, in the so-called Sahelian region (Figure 1). Almost whole the country's territory belongs to the Savanna zone whose annual precipitation varies from 400 mm in the north-east to 1200 mm in the south-west.

It has been indicated that the problem of desertification and soil degradation is serious in this country. It is believed that the onset of the problem was the recurrent drought during the 1970s and 1980s. But other factors such as the expansion of cropping field, the adoption of non-traditional cultivation methods including animal traction, and the increase of the number of livestock due to the rapid population growth

Figure 1 Location of Burkina Faso





**Figure 2 Study Site for Household Survey**

as well as poor agricultural productivity, are making the problem more serious. Because of the stagnation of agricultural productivity, the country stays to be one of the poorest countries in the world, and 61 percent of the country's total population is below the poverty line defined by "less than one dollar expenditure per day per capita." The poverty has made the rural population rely on external migration (mostly to neighboring Côte d'Ivoire) as well as remittance from the relatives living outside the country. It is estimated that such revenue constitute 10 – 20 percent of their total income. On the other hand, this regional migration has reduced population pressure on the land. However, due to the civil war in Côte d'Ivoire that took place in September 2002 (or so-called the Ivorian crisis), a considerable number of Burkinabés were obliged to return from Côte d'Ivoire to their home and the total number is estimated to be some 350,000 as of July 2003. That is, the crisis in the neighboring country has imposed unexpected income reduction as well as unexpected population pressure on rural Burkina Faso. Due to this shock (i.e. unanticipated, transitory worsening of economic welfare), agricultural households that are always poor even otherwise will try to increase income from agriculture and may conduct fertility-depriving cultivation, and therefore there is a risk of desertification. Hence, this research focuses on this shock-induced desertification.

## 2. Research Objective

The primary objective of this research is to investigate empirically the effect of the Ivorian crisis on soil degradation and desertification in Burkina Faso through behavioral change of rural households as responses to the shock caused by the crisis. Then, based on the analyses, this research aims to make policy recommendations to

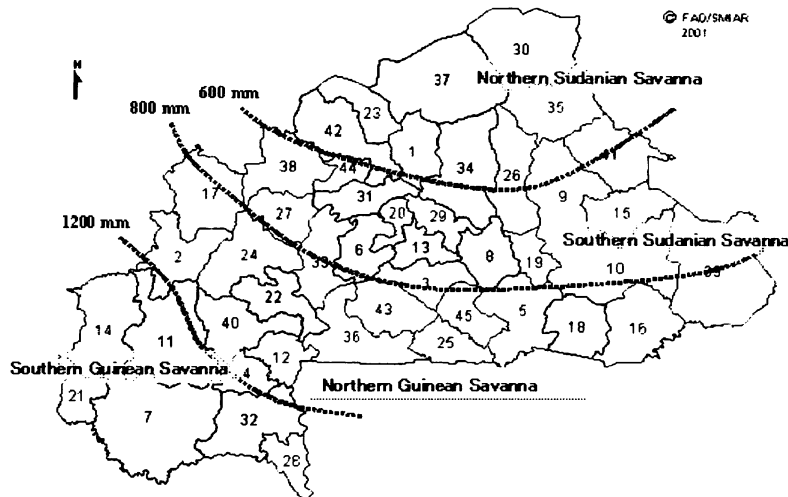


Figure 3 Study Site for Village Survey

avoid this kind of desertification specifically in Burkina Faso. In addition, we hope to contribute intellectually toward policy formulation to solve the global problem of soil degradation and desertification incurred by human activities.

### 3. Research Method

We selected our common study sites to serve for the region/village level data collection as well as for the household/plot level collection. For the household/plot level survey, 4 major agro-ecological zones in Burkina Faso were identified: the northern Sudanian Savanna zone, the southern Sudanian Savanna zone, the northern Guinean Savanna zone, and the southern Guinean Savanna zone, and two villages from each zone were chosen for the survey as shown in Figure 2. Then, thirty-two households were randomly drawn in each village from three sub-groups stratified by the ownership/adoption of animal traction technology. Thus, 256 households in total are subject to the intensive household survey. We conducted the survey from 2003 to 2005 so that we can construct a panel data set. Village 3 shown in Figure 2 (called Kolbila) was selected for a detailed soil study and the analyses of satellite image in 2004. The extensive village survey, on the other hand, was conducted in 208 villages selected randomly from 13 provinces out of 45 provinces in Burkina Faso (Figure 3). The 13 provinces were purposefully selected as they depend on migration more than others, according to the 1996 national census. The extensive village survey was completed in 2003, and a supplemental data were collected in 2004, then analyses were conducted in 2005.

### 4. Results

#### (1) Evaluation of the fragility of rural households against shock

This sub-theme examines if the transitory poverty caused by the crisis in

neighboring Côte d'Ivoire induces soil degradation and desertification in Burkina Faso. Household-level data collected before and after the crisis and village-level data collected after the crisis were used for the analyses. First, we confirmed that the crisis has caused an increase in rural population due to the returnees and poverty owing to the reduction of remittance from Côte d'Ivoire as well as income from migration to Côte d'Ivoire. Both of the impacts of the crisis have incurred an expansion of cropping area.

Quantitative analyses using the household-level data reveal that one-person increase causes 0.32 ha of area expansion and that 100,000 FCFA decrease of remittance causes 1.91 ha of area expansion. With respect to the agro-ecological zone, the reduction of remittance income is the most significant in the southern Guinean zone and the increase of household size is the largest in the northern Sudanian zone. Hence, there is a concern of negative effects of area expansion in those zones. The regression analyses also indicate that the impact of the crisis on the amount of remittance received depends on household ability to diversify remittance sources.

On the other hand, households' coping behavior, as it affects their market prices, may have influenced on the value of livestock holdings and non-agricultural income. But we could not have any clear figure from the whole sample households. However, based on the determinants analyses it is found that the value of livestock holdings decreased in the southern Sudanian zone and the southern Guinean zone because households sold their livestock to compensate the income loss. The regression analyses show that a reduction of 100,000 FCFA of livestock value causes 0.31 ha of area expansion. That is, the expansion of cultivated area is also taking place due to the reduction of livestock holdings in those zones.

The average amount of chemical fertilizer and manure/compost used by a household increased after the crisis, and as a result their input levels per hectare did not change even after the crisis although cultivated area expanded. The analyses show that the reduction of livestock holdings significantly reduces the use of manure/compost per hectare, particularly in the southern Sudanian zone. In this zone, since there is a significant positive correlation between livestock holdings and the amount of manure/compost use per hectare, the reduction of livestock holdings causes a decrease of manure/compost use per hectare. This finding combined with the previous one that the reduction of livestock holdings causes an expansion of cultivated area in this zone, there should be a risk of soil degradation.

A final survey conducted in two villages in the southern Sudanian zone in March 2006 reveals that the expanded cropping area has not reduced even after some returnees went back to Côte d'Ivoire. In addition, the reduction of income from the remittance from Côte d'Ivoire and migration to Côte d'Ivoire has not recovered at all, or even still decreasing. Therefore, it can be concluded that the shock caused by the Ivorian crisis is likely prolonged and an assistance to increase local income opportunities is necessary to avoid soil degradation and desertification.

## (2) Factors affecting farmers' adoption of soil conservation practices

Detailed survey on soil characteristics, vegetation and soil resources, areas and types of land use, components of household members, fertility maintenance under fallow system, and removal of nutrients by cultivation was conducted in Kolbila village, Central Burkina Faso, where the shock caused by the Ivorian crisis was conspicuously recognized.

Due to the crisis, the number of household members was temporally increased. Behaviors of farmers to absorb the increased population were the expansion of areas of cultivated field by opening fallow lands and the continuation of cultivation for the fields to be fallowed. The percentage of cultivation area to the total of fallow and cultivation areas reached 80 to 100 % for 5 farmers out of 6 farmers interviewed. Under the fallow cultivation system, it typically occurs that population increase expands cultivated fields. This trend may be continued until the shift of current cultivation system to an alternative system. These facts suggest that the conventional fallow cultivation system in Kolbila village has already been collapsed and there is little room to absorb further "shock" in future by this mechanism.

The above-ground biomass under different fallow period showed that 4 to 6 years were required to reach the 10 ton/ha level and 8 to 10 years to the maximum level (approx. 15 ton/ha). To estimate the nutrient removal by harvesting, the share of total-P in crop biomass in available-P in surface soil (0 - 10 cm) and that in total-P in vegetation (above-ground biomass) opened after different years of fallow period were estimated. The results show that the stock of T-P in the surface soil is equivalent to 4 to 6 years of harvesting and that of available-P in the fallow vegetation to 2 to 4 years. It means that the fallow system cannot function any more and the current prolonged cultivation decreases soil fertility if any external input of materials, e.g. manure or chemical fertilizer, are not applied.

Soil conservation measures employed in Kolbila village is stone line (generally called as *diguette*, or *kukokse* in local language) and grass line (*pidmkoaka*). No evidence was found that the installation of these measures was increased after the crisis. Temporal and rapid increase of household population did not necessarily motivate the people to move toward soil conservation. Numbers of livestock, hence the amount of manure production, were also not influenced by the crisis, although the villagers felt the necessity of manure and/or fertilizer application to maintain soil fertility. One reason of such slow action for soil conservation and livestock keeping is the shortage of household labor, which is preferentially allocated to cultivation activities.

## (3) Analysis of temporal changes of land use and vegetation in the villages

In response to recent civil unrest in Côte d'Ivoire in September 2002, several hundred thousand seasonal farm workers from Burkina Faso lost employment and were forced back to their native villages. Burkina Faso, one of the poorest counties in the

world has limited natural resources and a weak industrial base. Farmers have implemented a traditional crop-fallow system to maintain soil fertility. Sudden increase in population may have disturbed the traditional fallow cycle and altered the land use pattern. However, little information about the actual land use change was available. Satellite remote sensing techniques have proved promising in providing such information especially at a large scale. The objective of this study is to provide the spatio-temporal land use change information in Burkina Faso before and after the crisis in Côte d'Ivoire.

The use of middle resolution satellite imagery (30 m pixel size) from Landsat/ETM+ sensor enabled the compilation of detailed land use maps around the target villages. Two good quality image data from the right time, one before the cropping season and the other at the harvest time, were used. These satellite images were processed into Normalized Difference Vegetation Index (NDVI), which were then used to classify the land use types. High resolution commercial satellite imagery (sub-meter pixel size) from QuickBird was used to assess the accuracy of the classification results. The author found middle resolution satellite imagery to be capable of providing detailed crop land distribution and its temporal changes over time. However, the inability to acquire good quality image data at a specific time of the year resulted in excluding good portion (close to 80 %) of the total sample villages from the analysis. The mechanical problem of the Landsat/ETM+ sensor in 2003 further placed restriction on the use of image data from this satellite.

The use of low resolution satellite imagery (about 1 km pixel size) from the French SPOT/Vegetation sensor filled the information gap. The image data from SPOT/Vegetation have high temporal resolution (daily coverage of the entire world as opposed to 16-day repeat cycle of Landsat) and were resilient against cloud coverage. Ten-day maximum value composite (MVC) of SPOT/Vegetation through 1998 to 2004 was examined. A unique pattern in temporal profile of the pixels with cropland was identified. Extracting the unique pattern for pixels around the target villages helped the author to determine the spatio-temporal changes of cropland used intensity (CUI) into ordinal classes. The classification was carried out for each year between 2000 and 2004 and for over 70 % of the total sample villages throughout the country. The change in CUI varied greatly over space and no obvious spatial pattern could be found. Very weak but possible patterns which were identified include, 1) CUI declined in 2003 and then intensified in 2004 (Sudan Savanna North: annual precipitation less than 600 mm), 2) CUI intensified significantly in 2003 but declined sharply in 2004 (Sudan Savanna South: 600–800 mm), and 3) CUI stayed almost unchanged in 2003 but declined slightly in 2004 (Guinea Savanna North: 800-1000 mm). The most moist agro-ecological zone, Guinea Savanna South (over 1000 mm of rain per year), exhibited highly variable response in CUI over time and no unique pattern. Two years after the Ivorian crisis, agricultural land use in Burkina Faso appeared to resume to its normal

pattern. These findings suggested the author to conclude that the crucial determining factors of land use change in this country were mostly socio-economic conditions of each village rather than their locations.

The use of satellite remote sensing technique proved useful in providing objective land use pattern information over a large area. The new CUI classification algorithm developed in this study has implication to other semi-arid areas of the world where such objective land use information is lacking.

#### (4) Integration of sub-themes and a consideration of policy recommendation

This sub-theme is to integrate the other three sub-themes to develop policy recommendations for combating institutionally as well as technically desertification caused by the Ivorian crisis. In addition to this direct contribution to the problem studied, this research project aims to contribute intellectually to formulate effective policies for the global issues of soil degradation and desertification caused by human activities. Since the sub-themes (1) – (3) were assigned to each discipline: economics, soil science, and remote sensing, this fourth sub-theme deals with common, basic concepts for the project so that the team members can share them and will succeed the interdisciplinary research project. In 2005, this sub-theme considers, based on the outputs from the other three sub-themes, a policy recommendation for Burkina Faso where the reduction of income due to the Ivorian crisis persists even now.

In the southern Sudanian zone where the persisted impact is the most significant, a technological intervention should be placed in the medium-term trend of the shift of cultivation system. That is, farmers in this zone are required, even without the crisis, to adopt soil-fertility management technologies such as manure/compost, zai, stone line, and grass line in place of the current fallow system. In addition, there are few opportunities in this zone that give income equivalent to that earned in Côte d'Ivoire, and hence the expansion of cropping area due to the poverty is likely to continue. It necessitates financial aids from external agencies. For the villagers, such technical and/or financial aids are brought from outside, and their effectiveness depends on the villagers. The analysis in this sub-theme provides evidence that social capital among the villagers is one of the factors that affect the performance of external aids. This finding suggests that policymakers should pay attention to social capital and promote activities that will foster social capital among villagers. Since the negative impact of the Ivorian crisis will last long until enough income opportunities become available locally in Burkina Faso, medium-term policies to help local people in terms of social capital building will be effective.