Analyses of Household and Community Responses to Environmental Variability: The Case of Drought in the Semi-Arid Tropics

(Report on Feasibility Study in 2005)

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Household and Community Responses to Drought

Rural households in the semi-arid tropics, particularly in sub-Saharan Africa where credit and insurance markets are generally imperfect, have developed various kinds of risk-management and risk-coping mechanisms to respond unpredictable rainfall.[1] Some of the mechanisms such as borrowing and gift-receiving depend on relatives and friends in the same or neighboring villages, and hence the informal mechanisms will not work well in the case of severe drought where most of the households are simultaneously affected.[2] On the other hand, there are other kind mechanisms that rely on natural resources; for example, food gathering in the bush and utilization of wet valley bottoms.[3] As such, which mechanisms a household utilizes and how much extent the mechanisms are effective will be determined by private assets that the household has, common-pool natural resources that are available for the household, the severity of the drought, community's characteristics, and so on.[4] At the same time, the natural resource endowments could be affected by rural households' behaviors to cope with droughts. For example, if many households rush for wild food in the bush, the

[1] A detailed review about research on informal insurance mechanisms in developing countries is available in Chapter 8 of Bardhan and Udry (1999). It shows that rural communities have mechanisms to pool idiosyncratic risks incurred at individual households, although they are not perfect.

[2] In the semi-arid zone in West Africa, a drought-prone area, it is known that rural households have diversified their income sources to zones (i.e., the forest zone) and sectors (i.e., non-agriculture) that are not subject to the erratic rainfall in the semi-arid zone. For example, rural population in Burkina Faso relies on external migration (mostly to neighboring Côte d'Ivoire) as well as remittance from the relatives living outside the country, and such revenue is estimated to constitute 10 – 20 percent of their total income (Reardon et al. (1988)). It is not only drought but war, economic crisis, earthquake, flood, etc. that will cause a covariate shock from which many people in the same area suffer at the same time. There are limited number of studies on households' coping behavior in the case of covariate shocks: for example, the impact of the currency crisis on fertility in Mexico (Mckenzie (1999)), households' coping with flood in Peru Amazon (Takasaki et al. (2004)), the impact of the Great Hanshin-Awaji earthquake on households' expenditure (Sawada and Shimizutani (2004)), and the impact of war-induced covariate shock on soil fertility management in Burkina Faso (Sakurai and Savadogo (2006)). Please note that the concept of socio-ecological resilience is not limited to the case of drought, but can be applied other covariate shocks.

[3] In our preliminary fieldwork in Zambia we observed that people in the area affected by the severe drought in 2004/05 consume wild food such as cassava-like poisonous root. Such phenomena are often reported, but it is not yet known how much nutrient share such wild food constitutes.

[4] Of course, formal institutions play an important role in the determination of households' strategies of *ex ante* risk-management and *ex-post* risk coping. In our preliminary fieldwork in Zambia we observed a lot of aid (food as well as agricultural inputs for the next season) are being distributed in the drought-affected area by the government and NGOs. We can imagine that such aid may have created a moral hazard among farm households in the drought-prone area, although it must be rigorously proven by the data. In fact, farmers would not shift from maize to other drought-resistant food crops such as sorghum and cassava even though maize harvest totally failed in 2004/05 due to the drought. We believe that the moral hazard can explain farmers' crop choice at least partially.

resources will be exhausted and will not serve as a safety net in the next drought.[5] In other words, the resilience of households and that of ecosystem are dynamically inter-reliant. And because of this inter-reliance, households in the semi-arid tropics are often trapped in the vicious cycle of poverty and environment degradation.[6] This is the fundamental issue that the research project at which this feasibility study is aiming will address. Hence, this report on the feasibility study proposes a strategy to analyze socio-ecological resilience coupled with some review on the literature.

The research strategy consists of four parts. Part 1 discusses how to measure the risky event objectively, that is, rainfall. Then, part 2 concerns the endowments of resources available to households including physical, natural, human, financial, and social capitals. Part 3 is devoted to the analyses of households' behavior: risk-management before the rain, adjustment during the rainy season, and risk-coping after harvest. And finally in part 4, households' resilience in risky environment is evaluated in terms of income-smoothing, consumption-smoothing, and nutritious status.

1. Measurement of spatial and temporal distribution of plot-level rainfalls

It is well known that in the semi-arid tropics rainfall variability is very large even within a village. Moreover, crops are severely affected if there is no rain in the critical stage even annual rainfall level is high enough. That is, both spatial and temporal distribution of rainfall does matter. Nevertheless, most drought studies use annual rainfall observed at regional weather station, simply because spatial and temporal rainfall distribution at plot-level cannot be observed. This is the most significant weakness of existing drought studies. Hence, as the part 1 strategy it is proposed that daily rainfall on every sample household's plot will be recorded by utilizing small rain gauges, and the characteristics of spatial and temporal rainfall distribution within a small area will be analyzed.

Plot-level rainfall data have never been utilized in economic studies except for a pilot-type study done in semi-arid zone in southwestern Mali with a small number of sample households (Sakurai 2005a). Although sample size of the proposed study will be much bigger the pilot study in Mali, it will be useful to describe the Malian study briefly here so that the data collection method can be understood. In the Malian study, two villages are

[5] In the case of war-induced covariate shock in rural Burkina Faso, the negative income shock has induced an expansion of cropping area (Sakurai and Savadogo (2006)). This can be considered as the case where natural resources (soil and vegetation in bush) are exploited for coping with the shock, and if it leads soil degradation and desertification, the resources will never serve as safety net. Obviously, it depends on the robustness of soil and vegetation against human interventions.

[6] Although the vicious cycle of poverty and environment degradation is frequently mentioned (for example, a review by Duraiappah (1998)), its empirical evidence is still poor due to the lack of data and most of the existing empirical studies show only static relationship between the two (e.g. Cavendish (2000)). The difficulty may arise from two characteristics of the nexus. First, resource degradation induced by chronic poverty is slow and gradual, and hence is hardly observable. Second, chronic poverty itself may not cause resource degradation if the nexus is at a stable equilibrium point. Hence, the study being proposed here aims to overcome the data constraints in a multidisciplinary research team.

chosen for the study site and in each village about 30 households are randomly selected from wealth-based strata. Hence, the sample size is 60 households in total. The sample households were interviewed by field assistants who stayed in each village. They used structured questionnaires prepared in advance, which consist of several components listed in Table 1. Field assistants residing in each of villages interviewed the sample households every week starting from May, 2001 until the end of year 2003. On the other hand, about half of the sample households were selected for the measurement of plot-level rainfall. For each household, the most important plot in terms of food production was identified and an automatic rain gauge was set on the plot. Hence, the number of the rain gauges amounts to fifteen in each village. They did not select all the sample households for the rainfall measurement just because of the limitation of budget. Based on the data of daily precipitation at fifteen different locations in a village, daily precipitation levels at another fifteen plots of the remaining half of the sample households were estimated.

For rural households, rainfall is the most precious natural resource for their subsistence. Therefore, plot-level rainfall can be regarded as "private asset" for the owner of the plot. However, since rainfall availability is not predictable unlike other assets, rainfall should be classified as a risky asset, which does not appear in Table 1.

Table 1. Components of Questionnaires for Household Survey in Mali

Category	Frequency	Description of component
Household characteristics and household asset holdings	Once a year: At the beginning of the rain season	Demographics of the household
		Plot characteristics and crops (household common plots only)
		Ownership of the plots investigated
		Livestock holdings
		Asset holdings (agricultural equipment and buildings)
		Information sources of agriculture and technology
Agricultural activities	Every week: During cropping season	Agricultural activities conducted during the previous week
		Agricultural inputs and outputs during the previous week
		Purchases and sales of agricultural products during the previous week
Expenditures	Twice a month: During the survey period	Expenditures for goods and service during the last two weeks
Non-agricultural activities and transfer	Once a month: During the survey period	Consumption of food in stock during the previous month
		Labor supply to and income from off-farm activities during the previous month
		Gift given and received during the previous month

Adapted from Sakurai (2005a)

2. Investigation of households' capital endowments

How a household manages drought risk and copes with drought is a function of not only the magnitude of drought shock but also the resources available to the household. As mentioned in part 1, rainfall is also considered to be an asset, and can be included in the households' asset inventory. But since the measurement of plot-level rainfall is quite new and requires innovative technologies, it is treated separately in part 1. Therefore, in the

strategy part 2, households' capital endowments other than rainfall will be investigated.

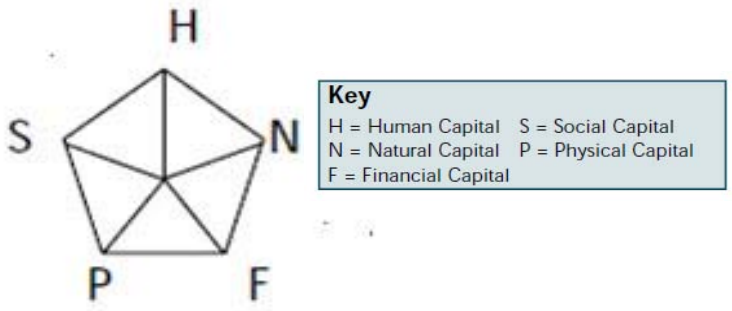

Figure 1. Five Capitals in SL Approach adapted from Ashley and Carney (1999)

UK's Department for International Development (DFID) is promoting the concept of "Sustainable Livelihood (SL) approach" for poverty alleviation, in which households' capital that supports their livelihoods is classified into five categories as shown in Figure 1 (Ashley and Carney 1999). This paper does not necessarily follow the SL approach, but adapts the categorization of households' capital as it is quite convenient. In the context of this proposed drought study, households' capital could be classified as follows: natural capital (rainfall, agricultural land, fallow land, forest land, livestock, and so on), physical capital (agricultural equipments, houses, and so on), human capital (composition of household members, their education level, their skills, their health status, and so on), financial capital (potential money-lenders, potential gift-givers, saving, and so on), and social capital (membership, network, trust, and so on).

There are several methodological issues in the measurement of the capital endowments, which are not explicitly treated in the Malian study presented above. First issue is how to measure the risk. As mentioned in part 1, since rainfall is a risky asset, the measurement of spatial and temporal variability of rainfall is critical. Similarly, it is necessary to quantify the risk of other assets, particularly of risky assets such as livestock holdings and human capital that are subject to diseases and death.[7,8] In other words, simple information on the number and the value of animals and the number of years of attending the school is not enough as they do not reflect their vulnerability. As far as the author knows, there is no standardized method to measure it or proxy variables to capture it, multidisciplinary research team including experts in human health and animal health should elaborate to develop methodologies.

Second issue is how to measure the physical amount of natural resources. Even though most assets are not so variable in the short-run, they are subject to depreciation in the long-run. The depreciation is determined by several factors including the utilization by the people, and

[7] As is well known, HIV prevalence rate in Zambia is very high even in rural area (about 15% according to UNAIDS/WHO (2004)). It means that human capital cannot be an effective asset to cope with external shocks such as drought. In addition, households may be discouraged to invest in such a risky asset, which will have a serious, negative consequence in the long run not only to the households themselves but also to the country as a whole. This is one of the most important research topics of this proposed study in Zambia. Yamano (2005) deals with this issue in his study in Kenya.

[8] Livestock diseases are a serious problem in Zambia. For example, in March 2004, outbreaks of contagious bovine pleuropneumonia (CBPP) were reported in southern and western provinces of Zambia (FAO 2004).

we know that soil is degrading and forest is disappearing. However, it is not easy to measure the rate of their depletion and the rate of their renewal. Moreover, it is hardly obtainable how much amount of resources exists and is available. The difficulty in measurement arises particularly when we consider the way to analyze data. Since this proposed study concerns household behavior under drought risk, the unit of analyses should be plot and household. Hence, just like plot-level rainfall, the endowments and the depreciation of natural capital need to be plot and household level. Such measurement may be technically possible, but will require tremendous amount of fieldwork. Thus, efficient methods to obtain necessary information need to be developed in collaboration with natural scientists. Note that the Malian study presented in part 1 does not include such natural resources in the capital inventory available to the households, as shown in Table 1. It is not because they are insignificant, but because it is too costly for a non-specialist to conduct physical measurement of soil and vegetation. The advantage of multidisciplinary approach of this research project is the involvement of natural scientists in the physical measurement such as soil and vegetation.

Third issue is about social capital.[9] A standard method to measure social capital by a set of questions has been established by the research team at the World Bank (Grootaert and Bastelaer 2002a; Grootaert et al 2003). And there is an ample of empirical studies that show positive effect of social capital on household income, technology adoption, common-pool resource management, etc. (for example Grootaert and Bastelaer 2002b; Grootaert et al 2002; Isham 2002; Krishna and Uphoff 1999). However, there are several problems if we adapt the standardized World Bank methodologies. First, although the World Bank questionnaires are comprehensive, they include so many questions and take so long time that they cannot be readily adapted in our study on socio-ecological resilience that should require a lot of different kinds of data. From a technical point of view, this is the most serous weakness of the World Bank approach. Moreover, there is still even a fundamental question as to how we can measure social capital. As Fukuyama (1999) points out many of the measurement of social capital such as trust, networks, civil societies are manifestations of social capital arising

[9] Bourdieu (1986) defines social capital as "an attribute of an individual in a social context," and syas "One can acquire social capital through purposeful actions and can transform social capital into conventional economic gains. The ability to do so, however, depends on the nature of the social obligations, connections, and networks available to you." It means that social capital, just like physical capital and human capital, is accumulation of past flows of investment less past flows of depreciation and somehow measurable. There are several ways to classify social capital, but with respect to the elements, two forms of social capital that correspond to the different roles of community should be distinguished. According to Krishna and Uphoff (1999), there are structural forms of social capital and cognitive forms of social capital. The structural social capital includes "rules, social networks, roles, procedures that facilitate mutually beneficial collective action by lowering transaction costs, coordinating efforts, creating expectations, making certain outcomes more probable, providing assurance about how others will act." On the other hand, the cognitive social capital means "norms, values, attitudes, and beliefs which create and reinforce positive interdependence of utility functions and which support mutually beneficial collective action."

as a result of social capital rather than social capital itself. Sobel (2002) addresses a causality issues in which he argues that some consequences of social capital are used as measurement of social capital itself in other context. Since there is no agreement regarding the measurement, or some even deny the existence of social capital as a kind of capital that individuals or households possess, this proposed research project need to consider how to incorporate the concept of social capital in the framework of socio-ecological resilience. Probably, one way to incorporate it will be from the viewpoint of social safety net that "social capital" may be providing communities or households. Such roles of social capital have been recognized, but empirical evidence is still little except for Sakurai (2005b) who shows that villages in Burkina Faso with higher social capital measured by group activities within the villages received more external aid when villagers suffered negative income shock due to the civil war in Côte d'Ivoire.[10]

Finally, we need to pay seroious attention to the property rights of the capital items. In the case of natural resources, resource ownership is often analyzed in terms of efficiency and equity: for example, which type of forest ownership is more efficient and which is more equitable, state property, common property, or private property? There are bunch of empirical studies in this field (e.g. Otsuka and Place 2001), but they are not investigated from the view point of socio-ecological resilience. Moreover, in the case of household capitals, gender related questions are typically addressed: whose capital (for example, land) is it, who controls the capital, who obtains the income from the capital, and so on. The biased asset ownership arises via gift and inheritance in the case of physical capital like land or by investment in the case of human capital like education. For example, see Quisumbing et al. (2004). Again, their consequences on socio-ecological resilience are still unknown. Compared with other types of capital, the ownership of social capital and its consequences are rarely discussed in the literature. There should be difference between the case where male household head has a network with outside and the case where his wife has a network with outside, in terms of social safety net, income generation, etc.

3. Analyses of households' behavior against rainfall variability

Given the various kinds of capital endowments discussed in parts 1 and 2 above, the question in part 3 is how households in the semi-arid tropics behave under the risky environment. Household behavior can be classified into three categories: risk management before the rain, adjustment during the rain season, and risk coping after the harvest. It is schematically summarized in Figure 2. At the beginning of the rain season, the household,

[10] With this regard, another way of classification of social capital may be useful. According to Narayan (1999) there are two types of social capital: bonding social capital and bridging social capital. The former works within groups to facilitate cooperation and/or collective action among members, while the latter improves the access to outside such as market, NGOs, and government. The bridging type of social capital is considered to facilitate the construction of social safety net with outside the community.

knowing the level of capital endowments as well as their risk (including the expected level of rainfall), makes decisions as to agricultural inputs, off-farm labor supply, livestock and other asset transaction, borrowing/lending, gift-giving/receiving, expenditure, consumption, and so on. With respect to agricultural inputs, crop and plot diversification is known to be one of the important strategies to mitigate rainfall risk. They include crop choice (e.g., drought-tolerant crops or drought-susceptible crops), varietal choice (e.g., early maturing or late maturing), and technology choice (e.g., with tillage or without tillage).

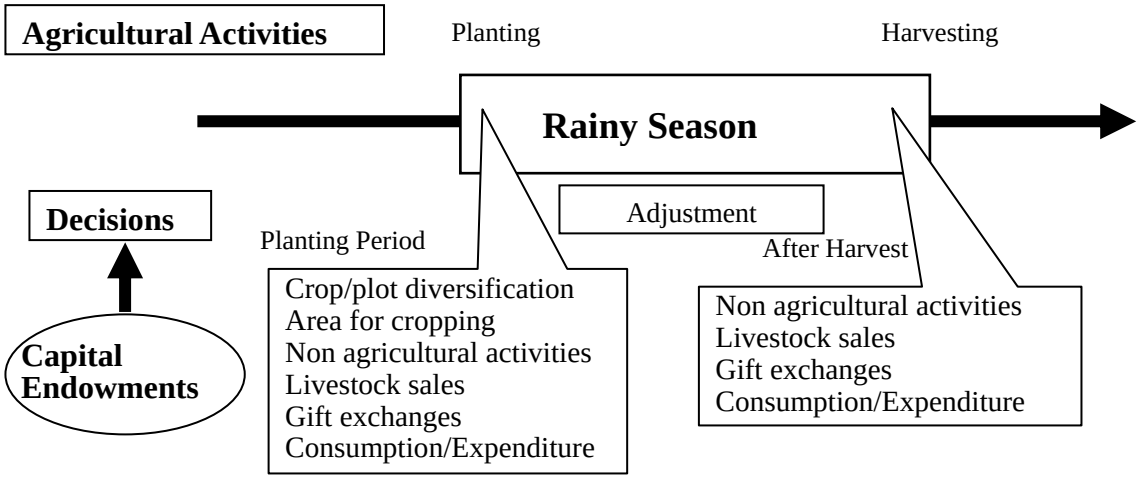

Figure 2. Household's Decision Sequence in the Semi-Arid Tropics

Then during the rain season, the household adjust its behavior with knowing the level of rainfall already given and modifying the expectation of the amount of rainfall still coming. Finally, after crop harvesting, the household decides how to cope with the results of the cropping season. If the realized income is less than the expected level, the household will do seasonal migration and off-farm labor supply as well as sales of some of capital endowments more than usual. Moreover, if such coping is not enough or expensive, the household will try to obtain income from natural capital (consuming and selling natural products such as wild fruits, fuelwoods, wild animals, and so on) as well as social capital (receiving personal gifts and/or loans and external aids from NGOs and government).[11]

The analyses in the proposed study will require detailed data about household behavior throughout the year. Such data will be collected by repeated household interview, at least once a week, considering that people easily forget about the details of their own behavior.

[11] As Solow (1999) points out, with this regard, social capital differs from natural or physical capital as the former does not depreciate or even appreciate when the owner utilizes it. Moreover, one cannot transfer social capital from one person to another, or one cannot liquidate social capital unlike natural or physical capital (Arrow 1999).

The household data will be matched with the daily, plot-level precipitation explained in part 1 and be used to investigate how households adjust their subsistence strategies to the varying environment during the rain season. Since such a study is very rare due to the limitation of available data, this proposed study is going to pioneer it.[12]

4. Evaluation of households' resilience

Finally, the performance of households' risk management and coping behavior will be evaluated from the viewpoint of resilience. Ignoring ecological aspect for a moment, the most standard criteria of households' resilience in economics is income smoothing and consumption smoothing as (see the review by Udry and Bardhan 1999): that is, a household with resilience can reduce risk *ex ante* by diversify income sources and can mitigate income shock by *ex post* coping, and consequently its income and consumption are little affected by the shock. Income and consumption smoothing should be evaluated not only within a year (i.e. seasonal variation) but also over years (i.e. yearly variation due to the rainfall), and therefore data collection from the same households need to be done several times within a year (ideally weekly) and over years during the project period.

However, there are several issues to consider. First whose consumption should be smoothed? Other than the capital endowments discussed in part 2, the discussion so far assumes implicitly that a household is the basic unit of decision making. But it is frequently observed in developing countries that individually earned income is not pooled in a household, and the allocation of consumption goods such as food within a household is biased (e.g., Quisumbing and Maluccio 2000).

Second is how to physically measure the income and consumption. Theoretically, it is not the monetary value, but utility derived from consumption and leisure that should be smoothed over time (taking the discount rate into account, of course). But because we cannot observe utility, instead of utility itself, income and consumption in monetary terms are used in empirical studies. However, in rural areas in the semi-arid tropics, monetary values may not be a good indicator of utility, for several reasons. First, just technical, the monetary values of wild food that people consume in case of crop failure may not be properly evaluated. Related with the first point, if the non-market prices of such products are very high as they are scarce, we may have to conclude that households' consumption in monetary terms is smooth even under the drought shock. It may not be correct.[13] Hence, in addition to the monetary

[12] The flexibility of households' farming practices during the rain season is one of the most important research topics of the JIRCAS's research project in Mali (see Caldwell et al. 2005). But Sakurai (2005a), using the same data set as Caldwell, analyses only ex ante risk management and ex post risk coping. Fafchamps (1993) also focuses on this issue, and examines the adjustment of labor supply in Burkina Faso.

[13] Not only the evaluation problem, but also there are questions as to the discount rate and the form of utility function. Namely, are the subjective discount rate and the form of utility function constant over the periods? If they change during the crisis period, how can we incorporate it in the analysis of consumption smoothing?

terms, we will need to see total calorie intake and its smoothness over time. For this purpose, physical measurement of in-kind income and food consumption (weight, volume, and calorie) is required for the evaluation of resilience.

Related with the above, required calorie may vary depending not only on age, gender, and body weight, but also on the level of activities. Naturally, those who work physically hard demand more food. It means that although basic calorie requirement can be considered fixed in the short-run (assuming that body weight does not change so much), real requirement depends on how much he/she consumes the calories, and hence endogenous. Putting it in other way, those who suffer from starvation will not work hard so that less calorie should be required to survive. In other words, the reduction of food consumption as well as activity level is a household strategy to cope with negative income shock. The question is if we regard it as a successful case of smoothed consumption as the required level itself is reduced, or as a case of failed consumption smoothing as the consumption level becomes low. Either way, if we have to take this issue seriously (I think that we should do it), we need to measure people's activity level and estimate their calorie consumption, and conduct anthropometrics: namely the measurement of body weight and height. Furthermore, if possible, we need to have a medical doctor check health condition of all the people in the sample households.

Conclusions

To achieve the proposed study, a huge amount of data will be required. Therefore, excellent collaboration in the multidisciplinary research team as well as sufficient amount of funding are indispensable.

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