Empirical Evidence of Resilience at Household and Individual Levels
-The Case of Heavy Rain in Drought-Prone Zone of Zambia-

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Abstract

There is a large volume of empirical literature on risk coping and consumption smoothing in the context of rural areas of developing countries where people's livelihood is always threatened by various risks. "Coping" implies the process of recovery from a shock. However, the existing literature does not consider time required for households and/or individuals to recover the level of consumption. Shortcomings of such analyses are that welfare impact of a shock can be underestimated because they cannot separate the shocks (i.e. reduction of consumption) and the recovery (i.e. increase of consumption) if recovery process starts before *ex post* data collection.

In order to improve the existing literature, this paper incorporates time dimension in the process of recovery from a shock. For this purpose, this paper adapts the concept of resilience from ecology and defines it in the context of consumption smoothing. Moreover, unlike most of previous studies on consumption smoothing, this paper utilizes weekly data collected before and after the happening of a covariate shock so as to provide empirical evidence of resilience.

This paper firstly provides an empirically-workable definition of "resilience" at household as well as individual levels. At the household level, resilience is based on the measurement of household food consumption per capita and is defined by the speed of the recovery of food consumption from a shock. At individual level, on the other hand, body weight is used for the measurement of resilience and the speed of the recovery of body weight from a shock is the definition of resilience.

Then, this paper demonstrates how to measure resilience using our own survey data collected in the Southern Province of Zambia, the most drought-prone zone in the country. Just after we started data collection in the field, unusual heavy rain took place in December 2007. Since the heavy rain damaged crops in the field and destroyed infrastructure such as road and bridge, we considered that it should have caused a shock to households and individuals in the study site. The analyses compare two sites: Site A and Site B. Normally Site A receives fewer rain and more susceptive to drought than Site B. But the heavy rain in December 2007 occurred in both sites almost equally. Nevertheless, only in Site A significant reduction of food consumption per capita and body weight was observed, and it took several months for both indicators to return to the original level. By definition, households and individuals in Site A are less resilient that those in Site B.

1. Introduction

Risks are everywhere and a part of rural life in developing countries. It is well known that rural households are practicing a variety of measures to manage risk *ex ante*, such as crop diversification and income diversification (Dercon, 2005). However, since such risk management measures are costly and imperfect, risk events such as drought often cause shocks to households, e.g. a decline of consumption. That is, shocks are almost inevitable in a risky environment. It does not necessarily mean that the impact of the shocks is significantly serious since households can mitigate the impact by taking various coping behaviors such as liquidating assets, increasing labor supply, receiving gifts, and so on (Dercon, 2002). Hence, as much as households have capacity to cope with shocks, they can mitigate their impact and as a result their consumption is smoothed. There is a volume of empirical literature that examines coping behaviors and tests consumption smoothing in rural areas of developing countries, generally demonstrating that rural households are usually able to smooth consumption in the case of idiosyncratic shocks and even in the case of covariate shocks they could smooth consumption to some extent depending on their capacity (Hoddinott and Harrower, 2005; and Dercon, Hoddinott, and Woldehanna, 2005).

However, the existing literature on consumption smoothing does not consider time that requires for households to recover the level of consumption. In order to test consumption smoothing, a panel data that contain at least two observations at different points of time are required. But since the interval between two observations is usually one year, or even several years, some shocks cannot be observed if consumption level recovers within the interval. One of obvious shortcomings of such analyses is that welfare impact of a shock can be underestimated if data collection after the risk event is conducted after the recovery or even in the process of recovery. Another problem is that such analyses cannot exactly estimate the magnitude of the shock (i.e. reduction of consumption) and the speed of recovery (i.e. time required for recovery) if recovery already starts when *ex post* data collection is conducted.

In order to improve the existing literature on consumption smoothing, this paper incorporates time dimension in the process of recovery from a shock. For this purpose, this paper adapts the concept of resilience from ecology and defines it in the context of consumption smoothing. Moreover, unlike most of previous studies on consumption smoothing, this paper utilizes weekly data collected before and after the happening of a covariate shock so as to provide empirical evidence of resilience.

2. Definitions

Gunderson et al (2002) distinguish two different ways of defining resilience in the ecological literature: one is engineering resilience and the other is ecological definition. The engineering resilience is "the speed of return to the steady state following a perturbation," conceiving ecological systems to exist close to a stable steady state. On the other hand, ecological resilience assumes multiple stability domains and is measured by "the magnitude of disturbance that can be absorbed" before instabilities shifts or flip a system into another regime of behavior. Thus, the concept of resilience can be immediately translated into economics. The concept of engineering resilience fits in economics that assumes a single stable equilibrium, while that of ecological resilience corresponds to multiple equilibria in economics. In the context of risk-coping and consumption smoothing, risk-coping implies at least short-run that a household moves back to the original state to keep consumption level unchanged or to minimize the time period where consumption level is below the normal. However, it is possible to assume a multiple equilibrium system in this context, for example the case where a household shifts its regular income source from agriculture to non-agriculture after a shock. The multiple equilibrium model seems to be more like adaptation in the long-run rather than coping in the short-run, and therefore the existing literature on risk-coping seems to implicitly assume a single equilibrium. In the second part of this paper, empirical analyses will be done using data collected weekly in the Southern Province of Zambia. Since the data covers only 6 months during one cropping season of 2007/08, the concept of engineering resilience fits better the situation. That is, resilience in this paper is "the speed of return to the steady state."

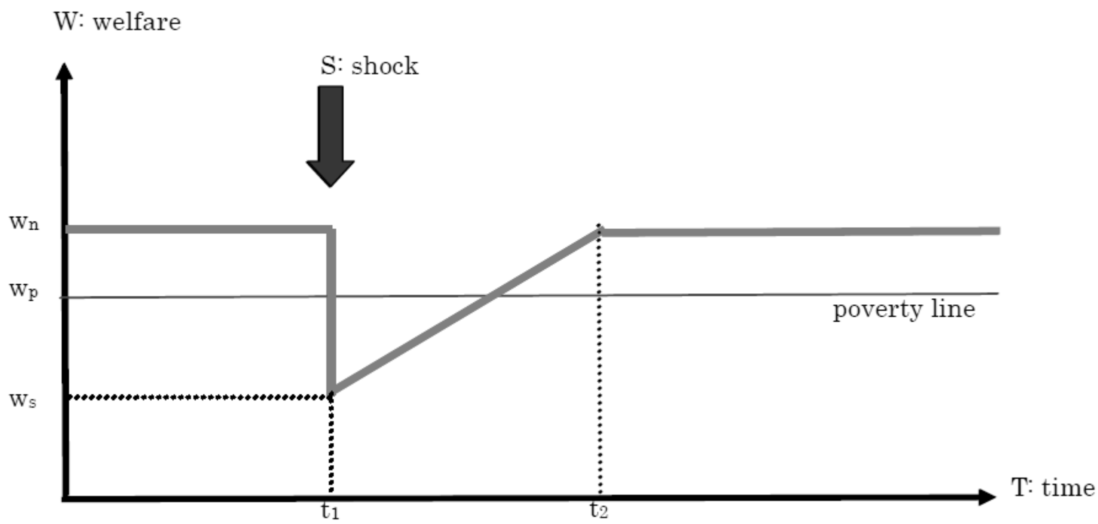

Figure 1. Schematic Definition of Resilience and Vulnerability

The definition is schematically presented in Figure 1. The vertical axis measures welfare state and the horizontal axis represents time. Figure 1 shows that welfare level at the steady state is W_n. From time 0 to time t_1 when a shock occurs, welfare level remains at the steady state level, then at time t_1 welfare level plunges from W_n to W_s due to the shock. At time t_1 welfare level starts recovering, and at time t_2 it returns to the original level, i.e. W_n. The recovery may not take place immediately after the shock; rather the lowest level of welfare may continue for a while. But the scheme is simplified. Figure 1 also indicates poverty line, which can be given at arbitrary welfare level, W_p, below which the household or the individual is considered to be poor.

Now following the definition of engineering resilience, resilience (R) can be defined in Figure 1 as below

$$R = \frac{W_n - W_s}{t_2 - t_1} = \frac{\Delta W}{\Delta t} \quad (1).$$

That is, resilience is measured as the slope of the welfare curve in Figure 1. Even if a shock occurs, if it does not affect welfare level at all (i.e. $\Delta W = 0$), resilience cannot be defined based on the definition above. However, in order to make the resilience indicator complete, R should be defined to be infinite when $\Delta W = 0$ (perfectly resilient). That is, if both $\Delta W = 0$ and $\Delta t = 0$, $R = \infty$. On the other hand, if welfare level never recovers, i.e. $\Delta t = \infty$, then $R = 0$ regardless of the magnitude of ΔW (no resilience at all).

Related indicators that are often used are vulnerability and poverty. Vulnerability (V) is an indicator how a household or an individual is sensitive to the shock concerned. Thus, the indicator requires the magnitude of the shock. If the magnitude is given by S, then vulnerability can be defined as

$$V = \frac{W_n - W_s}{S} = \frac{\Delta W}{S} \quad (2).$$

By definition, V is measured only at the time of shock, t_1. When two households are compared, if they are affected by a shock with the same magnitude, a household whose reduction of welfare is larger is more vulnerable regardless of the level of steady state welfare.

Poverty (P) is defined as the distance from the poverty line only when welfare level is below the poverty line. If welfare level is on or above the poverty line, the household is not considered to be poor, or $P = 0$. Thus, P is given by

$$\begin{aligned} P &= W_p - W \quad \text{if } W_p > W \\ &= 0 \qquad\qquad \text{if } W_p \leq W \end{aligned} \quad (3)$$

where W is welfare level at the time when poverty is to be measured. It is important to note that poverty can be measured at any point of time. In the case of Figure 1, $P = 0$ from time 0 to time t_1, $P = W_p - W_s$ at time t_1, then P is decreasing and returns to 0 at a certain point between t_1 and t_2 where $W = W_p$. After this point, P stays 0.

Note that if surveys are conducted before t_1 (i.e. before the shock) and after t_2 (i.e. after the recovery), no matter how low W_s is (or in other words, no matter how large ΔW is), $R = \infty$ (i.e. perfectly resilient), $V = 0$ (i.e. never vulnerable), and P is always 0 (i.e. never poor). This is the case of the underestimation of welfare impact of a shock, as mentioned previously. In addition, in such cases it is not possible to distinguish between "never vulnerable" (i.e. $\Delta W = 0$) and "highly resilient" (i.e. $\Delta W > 0$ but W returns to W_n before the second survey). It is important to distinguish them empirically because they should have different policy implications.

3. Empirical Strategies

In order to measure resilience based on the definition given in the previous section, welfare need to be defined and measured first. Since this paper concerns resilience at household level and individual level, welfare should be measured at those levels. In the case of household welfare, it can be measured by the real value of food consumption per capita, the calories of consumed food per capita, and the real value of total consumption per capita. In the case of individual welfare, on the other hand, anthropometric data should be used for welfare indicator such as body weight and skin-fold thickness.

Then, risk event must be specified, from which the speed of welfare recovery will be measured as resilience according to definition (1). If the risk event is covariate such as drought, heavy rain, war, economic crisis, and so on, a common time period during which the speed of recovery is measured can be introduced. But idiosyncratic risk events such as illness, death, divorce, theft, and so on can also be considered in the same framework. In such a case, time period for recovery is also household or individual specific.

The risk event in question does not necessarily cause a shock to households or individuals. Since by definition a shock is a decline of welfare level immediately after the risk event (i.e. before recovery starts), if a household or an individual is never vulnerable (i.e. $\Delta W = 0$) there is no shock in spite of the risk event.

4. Data

This paper uses the data collected as part of Resilience Project of Research Institute of Humanity and Nature. The Project's study area is in the Southern Province of Zambia, the most drought-prone zone in the country. Within the study area, three agro-ecologically-distinctive sites, namely Site A, Site B, and Site C, are selected for detailed household survey. The three sites are spread over the slope adjoining Lake Kariba: Site A is located on the lower terrace of the slope on the lakeshore; Site C is located on the upper terrace of the slope on the southern edge of Zambian plateau; and Site B is located on mid-escarpment between the two sites. Based on village census conducted before the rainy season in 2007, 16 households in each site, thus 48 households in total, were selected for household survey.

The household survey consists of three components: (i) household interview; (ii) household members' anthropometric measurement; and (iii) rainfall measurement on household's plot. Each household is interviewed conducted every week by an enumerator using structured questionnaires. Information obtained from the weekly interview is as below:

- Food and non-food consumption
- Input/output and stock of agricultural production
- Other economic activities (non-agricultural work, natural resource collection, etc.)
- Transfer received and sent
- Time use of each household member
- Health condition of each household member (self-reporting)

In addition to the weekly interview, annual and monthly interviews are also conducted to obtain household information on asset holdings and demographics. For the anthropometrics, the same enumerator measures household members' body weight, height, skin-fond thickness, and upper-middle arm circumference using special instruments at the time of interview. Plot-level rainfall is recorded every 30 minutes by a rain gauge installed on a plot of each sample household. The data collection started in November 2007 at the beginning the rainy season of 2007/08 and continued throughout the rainy season.

Unfortunately, due to technical problems in logistics, data collected in Site C is not complete, i.e. large amount of missing data in household interview. Therefore, this paper uses data from Site A and Site B only.

5. Results

5.1 Risk Event: Heavy Rain

First, risk event must be identified. Project's researchers and enumerators working in the field experienced very heavy rain in December 2007, just after data collection had started in November 2007. The heavy rainfall and associated flood damaged crops just planted in November and destroyed infrastructure such as road and bridge through which people and vehicles access to town. According to villagers, such heavy rainfall is very rare or even once a several decades in the study area, which is known as the driest in the country and drought-prone. Although we cannot know how unlikely such an event takes place in the villages we selected since there is no long-term, reliable precipitation record around the study area, based on our own observations and information given by villagers we considered that the heavy rain in December 2007 is an unexpected risk event that should have caused a shock to villagers.

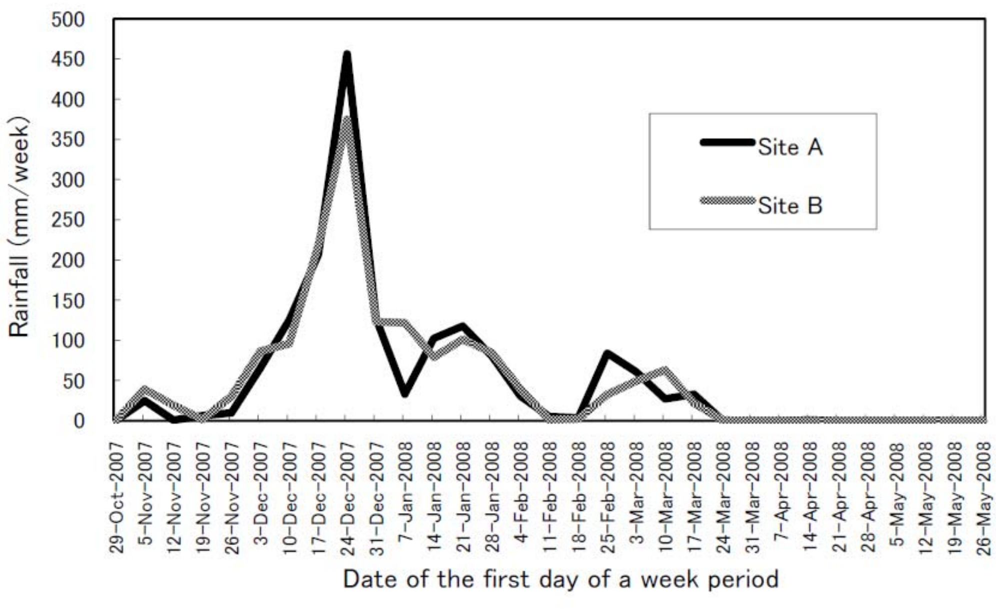

Figure 2. Weekly Precipitation in the Study Sites

Figure 2 presents weekly precipitations during the rainy season 2007/08. The weekly precipitation is obtained as the average of 16 rain gauges installed in the field of sample households in each study site. Out of 16 rain gauges, 6 rain gauges in Site A and 3 rain gauges in Site B give incomplete data due to errors, and such incomplete data are not used for calculating weekly precipitations. As shown in Figure 2, both Site A and Site B had heavy rain in December 2007, particularly during the week starting from December 24th.

Table 1. Annual Precipitation of 2007/08 Cropping Year

	Number of Rain Gauges	Mean (mm)	St. Dev. (mm)	Max. (mm)	Min. (mm)
Site A	10	1603	48	1699	1559
Site B	13	1586	59	1673	1488

Table 1 summarizes precipitation data aggregated at the annual level. It is generally believed from the experience that Site A has smaller mean and smaller spatial variation of precipitation, and hence is more frequently affected by drought. However, in 2007/08 the annual precipitations in the two study sites are very close; Site A's precipitation is even higher although the difference is statistically not significant. On the other hand, spatial variation of annual precipitation is higher in Site B than in Site A, which may reflect the hilly landscape in Site B and is as normally expected. These observations suggest that the heavy rain shock should be severer in site A than in site B.

5.2 Household Welfare Indicator: Consumption per Capita

The weekly household interviews ask about food consumed by the household members during the last week. The food includes self-produced food, purchased/gifted food, and edible items collected in the field (bush and lake).

In order to construct a welfare indicator from the food consumption data, all the food items are evaluated using market price and if market price is not available values are evaluated by respondents. Then, the value of the food consumed is aggregated at the household level for each week and the total value is divided by the adult equivalent household size; in this way food consumption per week per adult equivalent in nominal monetary term is obtained. Finally, the nominal values are deflated by the local food price index[1] to obtain food consumption per week per adult equivalent in real monetary term, which is used as the welfare indicator of household in this study.

Now in order to know the fluctuation of food consumption after the heavy rain event in the week of December 24th, the following equation is estimated for each zone separately.

[1] Based on the weekly interview on food consumption, locally-common food basket is determined first. The food basket is fixed during the survey period and common to all the study sites: The basket for 16 households per week consists of 6.1 buckets of maize, 1.8 bags of 25 kg bag of maize flour, 2.6 packets of dried small fish, 2.8 piles of dried fish. The cost for purchasing the basket is evaluated every week using their market prices. Each study site has different market prices and they fluctuate a lot during the cropping season, as a result the cost differs spatially as well as temporally. The relative cost is used as the food price index for this study, setting the cost of the first week in Site A to be 100.

$$\ln(C_{iw}) = \alpha + \beta_1 Q_{iw} + \beta_2 Q_{iw}^2 + \sum_{w \geq 8} \delta_w D_w + HH_i + \varepsilon_{iw} \tag{4}$$

where ln is the operator of natural logarithm; C_{iw} denotes household i's (i = 1, 2, . . . , 16) real value of food consumption per adult equivalent in week w (w = 1, 2, . . . , 27); Q_{iw} denotes household specific weekly rainfall recorded household i's plot in week w; D_w denotes a binary dummy variable for the week w; HH_i is household i's fixed (i.e. time-invariant) effect; α, β_1, β_2,and δ are parameters to be estimated; and ε_{iw} is the residual. The week dummies start at week 8, which corresponds to the week of December 24th. Thus, equation (4) assumes that before the heavy rain event household consumption level remains at the normal level on average and after the heavy rain event household consumption level may start fluctuating. Thus, the fluctuation of average food consumption at the study site is captured by these week dummies. On the other hand, the household fixed effect is meant to capture household fixed factors that affect consumption level such as asset holding, age and gender composition, type of occupations that may have different energy requirement, soil type and plot location that may affect agricultural productivity, and so on.

Table 2. Results of Fixed Effect Regression of Household Consumption Equation[1]

	Coefficients Estimated			Test if the weekly dummies (D_w) jointly have any effect	R squared	Number of observations (16 households by 27 weeks)[2]
	Constant (α)	Weekly Rainfall (β_1*10^3)	Weekly Rainfall Sq (β_2*10^6)			
Site A	6.80 (0.08)***	2.63 (0.78)***	-5.54 (1.42)***	Yes***	0.18	288
Site B	6.16 (0.14)***	1.40 (0.57)**	NA[3]	Yes***	0.10	294

Standard errors are in parentheses. *** and ** are indicate significance level 1% and 5% respectively.
[1] Fixed effect regression is done for Site A and Site B separately.
[2] The panel data is unbalanced due to missing data in household interviews and/or rainfall data.
[3] When both weekly rainfall and its squared term are included, neither is significant probably due to multicollinearity. But if the squared term is dropped, weekly rainfall has a significantly positive effect. The exclusion of the squared term does not change other estimates much.

The results of fixed effect estimation of equation (4) are summarized in Table 2. In Site A plot specific weekly rainfall has a significantly positive effect on the consumption during the same week, but the negative coefficient for the squared term implies that the effect becomes negative above a certain level of rainfall, which suggests the existence of heavy rainfall shock. The level where the impact becomes negative is calculated at about 48 mm/week. Based on the weekly precipitation as shown in Figure 1, heavy rainfall in December 2007 and even rainfall in January 2008 are considered to have a negative impact on household's food consumption. Note that the heavy rainfall has an immediate impact on food consumption before the time of harvest when they will realize a poor yield, which implies that the damage caused by the heavy rain created lower expectation of harvest and discouraged food consumption even before the harvest. Such a negative effect is not observed in Site B. Rather, as shown in Table 2, the coefficient estimated is positive and significantly different from zero, if the squared term of weekly rainfall is dropped. It means that the more rainfall received, the more food is consumed even before harvest in Site B.

As for the weekly dummies, after controlling for the plot specific weekly rainfall, they are jointly different from zero. Those dummies capture the deviation of village mean consumption from the normal level, thus if mean consumption fluctuates a lot after the heavy rain, the heavy rain is considered to create a covariate shock in the study site.

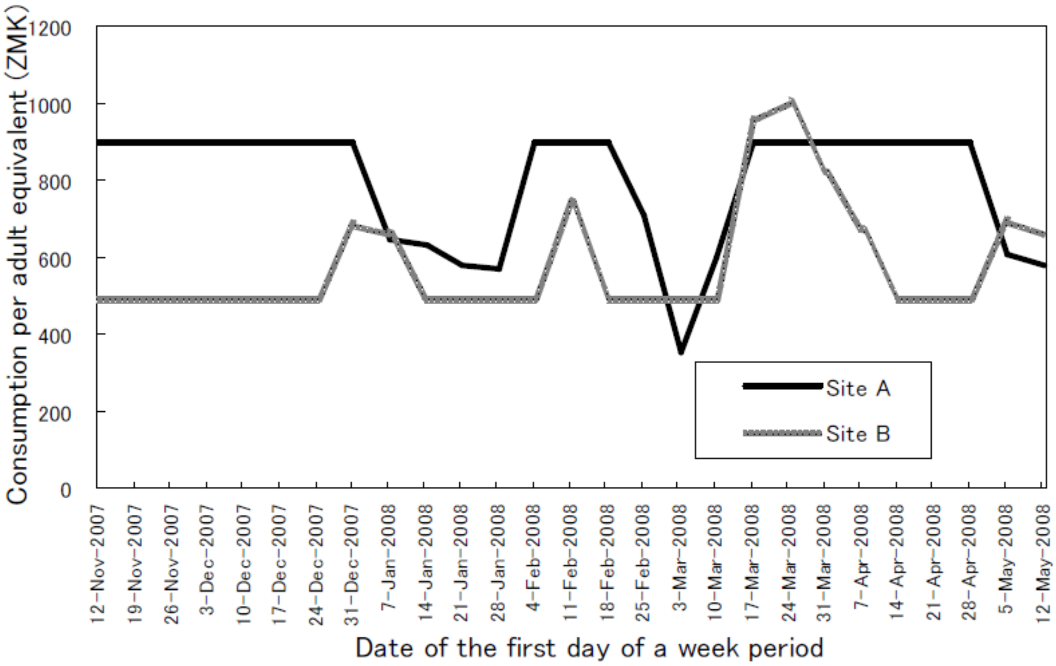

Figure 3. Deviation of Food Consumption from the Normal Level

Note: Average food consumption before the heavy rain is assumed to be the normal level of food consumption. The deviation from the normal level is obtained from the coefficients for weekly dummies specified in equation (4). If estimated coefficient is not statistically different from zero, food consumption of the week is the same as the normal level.

Figure 3 presents the fluctuation of village mean consumption. It is assumed that the mean consumption level is constant at normal level before the heavy rain during the week of December 24^{th} (or week 8). Then, after week 8, if the coefficient of a week dummy is not significantly different from zero, consumption level is considered to be the same as before week 8, but if the coefficient of a week dummy is significantly different from zero, consumption level is adjusted based on the magnitude of the coefficient estimated. As shown in Figure 3, a negative impact of the heavy rain is observed immediately after the event in Site A, and it persists for four weeks. Then the consumption level recovers, but another small peak of rainfall again decreases consumption in February/March 2008. Consumption level becomes normal after start harvesting in March 2008. On the other hand, in Site B, there are two small rises of consumption in December 2007 and February 2008, but the reason is unknown. Then, the large peak in March 2008 should be due to harvest, particularly due to the consumption of fresh maize whose market value is very high. Therefore, the heavy rain in December 2007 has no impact on household welfare in Site B.

With respect to resilience at household level, households in Site B is more resilient than those in Site A on average since by definition Site B shows "perfect resilience." However, even households in Site A are resilient against the heavy rain shock as their welfare level seems to have recovered in a few weeks.

5.3 Individual Welfare Indicator: Body Weight

This paper uses body weight as a welfare indicator at individual level. In the household survey, body weight of all the household members available at the time of interview is measured using a portable digital scale. Then, the indicator is defined as the deviation of individual's body weight from his/her own average weight.

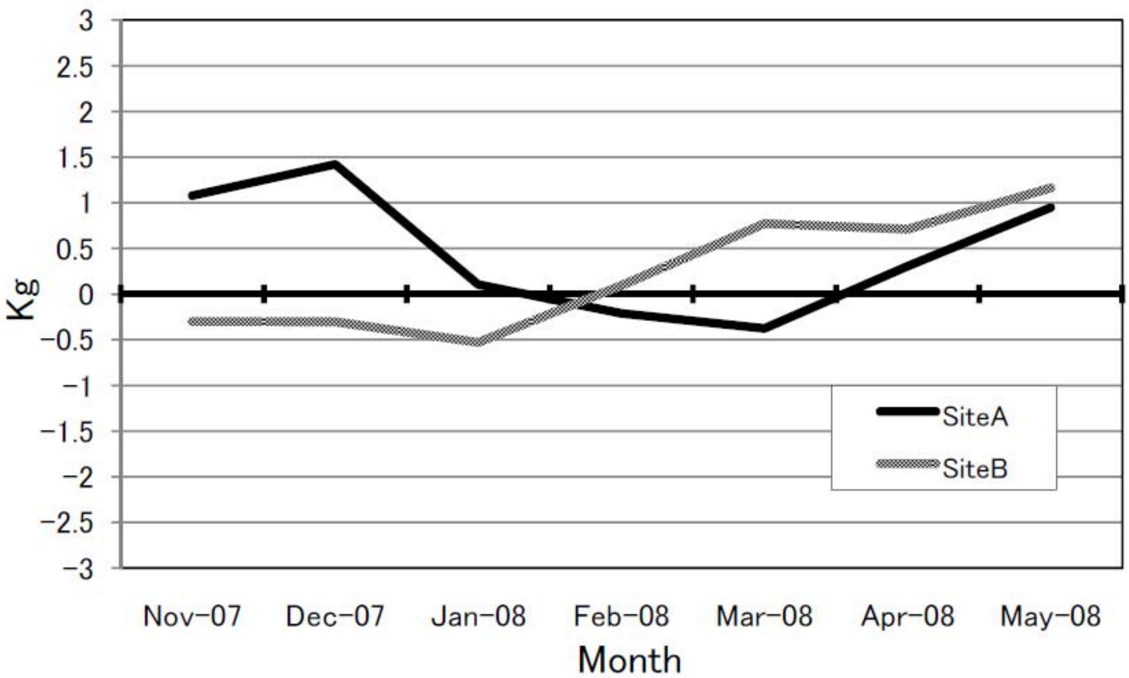

Figure 4. Deviation of Body Weight from the Average

Note: The graph shows body weight change during 2007/08 cropping season. The deviation is calculated as the difference between individual's body weight of the month and his/her annual average, both of which are obtained from weekly body weight measurements. The graph presents the mean value of deviations of 31 adults for Site A and that of 40 adults for Site B. Adults are defined as anyone whose age is 16 or above it regardless of the sex.

Figure 4 presents the trend of the welfare indicator for Site A and Site B. It is clear that adults in Site A decreased their body weight in January, February, and March 2008, then recovered in April and May 2008, which is after harvest. In Site B also a decrease of body weight is observed in January 2008, but the decline is very small compared with the case of Site A, and in February 2008 body weight started increasing, which is much earlier than in Site A. The distinctive patterns of body weight change are consistent with the food consumption presented in Figure 3.

With respect to resilience defined in equation (1), the speed of recovery in Site A (imaginary slope between January - May 2008) is much smaller than in Site B (slope between January – February 2008). Thus, by definition, Figure 4 indicates that individuals in Site B are more resilient than in Site A.

6. Conclusions

This paper firstly provides an empirically-workable definition of "resilience" at household as well as individual levels. At the household level, resilience is based on the measurement of household food consumption per capita and is defined by the speed of the recovery of food consumption from a shock. At individual level, on the other hand, body weight is used for the measurement of resilience and the speed of the recovery of body weight from a shock is the definition of resilience.

Then, this paper demonstrates how to measure resilience using our own survey data collected in the Southern Province of Zambia, the most drought-prone zone in the country. Just after we started data collection in the field, unusual heavy rain took place in December 2007. Since the heavy rain damaged crops in the field and destroyed infrastructure such as road and bridge, we considered that it should have caused a shock to households and individuals in the study site. The analyses compare two sites: Site A and Site B. Normally Site A receives fewer rain and more susceptive to drought than Site B. But the heavy rain in December 2007 occurred in both sites almost equally. Its impact, however, differs between the two sites. In Site A, an immediate decline of food consumption per capita and a gradual reduction of body weight are observed. While the consumption recovered after several weeks, it took several months for the body weight to return to the original level. In Site B, on the other hand, heavy rain does not induce such shocks. Hence, households and individuals in Site A are considered to be less resilient that those in Site B, but those in Site A still demonstrate resilience against the heavy rain shock.

In conclusion, this paper shows that the concept of resilience can be applied to the analyses of household behavior in the variable environment and that food consumption and body weight are useful welfare indicators to measure household resilience and individual resilience. Resilience obtained in such ways will be used in the future study to identify determinants of household/individual resilience such as assets, education, networks, etc. In addition, the effect of household coping behavior including *ex post* migration, off-farm labor supply, and gift-receiving on resilience will be investigated.

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