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What determines farmers' resilience towards ENSO-related drought? An empirical assessment in Central Sulawesi, Indonesia

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Abstract Crop production in the tropics is subject to considerable climate variability caused by the El Niño-Southern Oscillation (ENSO) phenomenon that is likely to become even more pronounced during the twenty-first century. Little is known about the impact of ENSO-related drought on crop yields and food security, especially at the household level. This paper seeks to contribute to closing this knowledge gap with a case study from Central Sulawesi, Indonesia. Its main objective is to measure household resilience towards drought periods and to identify its influencing factors to deduce policy implications. Using indicators for consumption expenditures, we construct an index measuring household drought resilience; we then apply an asset-based livelihood framework to identify its determinants. Most of the drought-affected farm households are forced to substantially reduce expenditures for food and other basic necessities. Households' drought resilience is strengthened by the possession of liquid assets, access to credit, and the level of technical efficiency in agricultural production. The results suggest a number of policy recommendations, namely improvement of the farmers' access to ENSO forecasts, the provision of credit and savings products to facilitate consumption smoothing, and the intensification of agricultural extension in view of low levels of productivity found in agricultural production.

1 Introduction

Crop production in the tropics is subject to considerable climate variability that is mostly attributable to the El Niño-Southern Oscillation (ENSO) phenomenon (Salafsky 1994; Amien et al. 1996; Datt and Hoogeveen 2003). In Southeast Asia, El Niño is associated

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with comparatively dry conditions: Quinn et al. (1978) found that 93% of droughts in Indonesia between 1830 and 1953 occurred during El Niño years. In four El Niño years between 1973 and 1992, the average annual rainfall amounted to only around 67% of the 20 year average in two major rice growing areas in Java, Indonesia, causing a yield decline of approximately 50% (Amien et al. 1996). There is evidence that, in concert with global warming, the frequency and severity of extreme climatic events will increase during the twenty-first century, and the impacts of these changes will notably hit the poor (McCarthy et al. 2001, pp. 6–7).

Several macroscale studies model the impact of climate variability and climate change on crop production in the Asia-Pacific region (see Zhao et al. 2005, for a review). However, in order to evaluate specific climate variability impacts, including the strategies of the local population towards income and consumption smoothing, it is necessary to study the associated systems at the community and household levels.

The Intergovernmental Panel on Climate Change identified the "quantitative assessment of the sensitivity, adaptive capacity, and vulnerability of natural and human systems to [...] climatic variation" as one of the high research priorities with respect to policymaking needs (McCarthy et al. 2001, p. 17). Against this background, the objective of the present paper is (1) to investigate the ex-ante and ex-post risk response strategies taken by farm households in the case of ENSO-related drought in a rainforest margin area in Indonesia, (2) to measure household resilience towards these drought periods, and (3) to identify factors which influence drought resilience in order to derive policy recommendations.

The remainder of the paper is structured as follows: a brief description of the research area is provided in Section 2; Section 3 develops the analytical framework applied to measure drought resilience and identify its influencing factors, while Section 4 provides a description of the data and definition of the variables used in the analysis; findings are presented in Section 5 and discussed in Section 6; finally, our conclusions are summarized and policy recommendations are derived in Section 7.

2 Description of the research area

The research area encompasses the Palu River watershed in Central Sulawesi province, Indonesia. Its mountainous topography results in a distinct rainfall gradient, with the coastal zone receiving only 600 mm of rain p.a., while precipitation exceeds 3,000 mm at higher elevations (WWF 1981). Therefore, agricultural land use is very location specific, depending on local rainfall, topography and soil properties. In general, the major food crops are irrigated rice and maize, which are typically grown twice a year, and the dominant cash crops are cocoa and coffee. Table 1 provides a farm-level overview of the area shares devoted to these crops, reflecting their relative importance; it differentiates between the three subdistricts of the research area, which are located at different elevation levels and cover separate valleys. The area shares differ significantly between subdistricts, as indicated by different superscript letters. The cropping system in Biromaru is based on irrigated rice, whereas in Palolo cocoa is the dominant crop. In Kulawi, coffee, irrigated rice and cocoa all take up sizeable portions of the average farm. Overall, irrigated rice and cocoa are the two dominant crops grown in the research area, with mean farm-level area shares of 36% and 31%, respectively. Rice, with an average gross margin of 2.4 million IDR[1] per hectare and cropping season, is used both for own consumption and sale; cocoa is a particularly

[1]Indonesian Rupiah. 1 US$=8,900 IDR (February 2003).

Table 1 Mean area shares of the most important crops in Central Sulawesi at the farm level, differentiated by subdistrict

Subdistrict (Elevation in m a.s.l.)	N	Mean farm size (ares)*	Mean share of the total farm area planted with...**			
			Irrigated rice (%)	Maize (%)	Cocoa (%)	Coffee (%)
Biromaru (50–90)	96	137.1[a]	50.3[a]	9.6[a]	16.6[a]	1.1[a]
Palolo (550–650)	71	182.6[b]	18.4[b]	11.1[a]	58.5[b]	6.6[b]
Kulawi (560–980)	61	236.9[b]	32.2[c]	1.2[b]	23.1[c]	40.1[c]
Total	228	178.0	35.5	7.8	31.4	13.2

*Homogeneous subsets (a, b) based on Games–Howell test, $P<0.05$

**Homogeneous subsets (a, b, c) based on Wilcoxon–Mann–Whitney test, $P<0.05$

important source of income with a mean gross margin of 9.3 million IDR per hectare and year.

3 Analytical framework

The conceptual framework used to analyze household drought resilience employs an asset-based approach to social risk management presented by Siegel and Alwang (1999). Its theoretical underpinnings draw on Sen's (1981) 'entitlement approach' and the sustainable livelihoods framework (e.g. Scoones 1998; Devereux 2003). The investigation is broken down into three components: (1) the risk of drought; (2) the household's response to the risk of drought, and (3) the outcome, i.e. the final impact of a drought on the welfare of the household.

3.1 The risk of drought

The term 'risk' refers to a situation where alternative outcomes exist and information is available to generate probabilities of these outcomes, as opposed to 'uncertainty' which refers to situations where these probabilities are unknown (Roumasset 1976, p. 13). Based on the analysis of 28 El Niño episodes in Indonesia and the Philippines in the period between 1866 and 1992 by Harger (1995) one can conclude that, on the average, comparatively dry conditions occur every 4.5 years, which means that the probability of drought is a substantial 22%. However, there is considerable temporal variation: typically, El Niño recurs every 2 to 7 years (NOAA 2005). Figure 1 illustrates the ENSO-related variability of monthly rainfall in Central Sulawesi, showing that the June–October period is particularly affected; in El Niño years rainfall is reduced to 62% of the average during this period.[2] Moreover, the distribution of planting times of rice in the research area is displayed: while there are no clearly defined planting periods in the equatorial climate, the distribution peaks in January/February for the first and in June to August for the second rice crop. Hence, the El Niño-related depression in rainfall largely coincides with the second cropping season.

[2]Since local climate patterns in the mountainous research area are very complex, the severity of a drought in terms of length and intensity varies depending on the specific location.

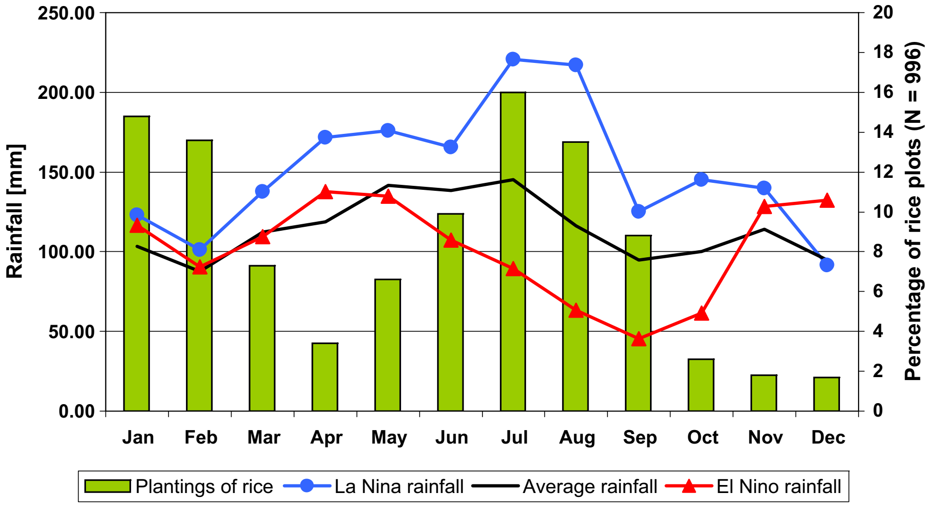

Fig. 1 ENSO-related variation of monthly rainfall and temporal distribution of rice plantings in Central Sulawesi. Sources: Own survey (plantings); Dinas Pertanian Kabupaten Donggala (rainfall). Rainfall data are averages from 24 rain gauges throughout Central Sulawesi for the period 1981 to 1999, whereby 1982, '87, '91, and '97 are considered as El Niño, and 1988, '96, and '98 as La Niña years

3.2 Risk response

In general, household risk management strategies involve ex-ante and ex-post activities. Ex-ante activities may serve to reduce the probability of the occurrence of a hazard or to mitigate the potential negative impact of a hazard through precautionary measures.[3] Ex-post coping activities aim at smoothing consumption once the household has already been affected by the hazard (Morduch 1995).

Apart from the external economic, social, and political frame conditions, a household's risk management largely depends on its asset base and attitude toward risk. Assets interact with risk in several ways. First, the sources of risk affect households through their impact on the value and productivity of their assets. Second, households may reallocate their assets in response to risk. This reallocation not only affects short-term returns and their variability, but also the longer-term vulnerability of households through its impact on savings and investments (Zeller et al. 1997, pp. 22–23). Because of the great influence of the asset portfolio on household risk management, our analysis of drought resilience employs an asset-based approach.

3.3 Measuring drought resilience

Resilience is defined to be "the ability of a system to absorb change" (Ellis 1998, p. 14). Since household risk management aims at smoothing consumption (Morduch 1995), we measure resilience as the observed degree of drought-induced expenditure reductions for basic necessities; to capture the impact on the consumption of home-produced food, we also account for absolute differences in the consumption of selected food items between the

[3]We did not consider drought prevention strategies since the only thinkable strategy that may be employed at the household level is permanent migration to an area less affected by drought.

'normal' and the drought situation (see Table 2, Section 5). The share of expenditures during the drought relative to the 'normal' situation is expected to be positively correlated with household drought resilience. The differences in food consumption between the 'normal' and the drought situation are hypothesized to be negatively correlated with resilience in the case of superior foods, whereas a positive correlation is expected in the case of inferior foods. In the research area, rice and meat are superior, i.e., preferred foods, whereas maize is generally perceived to be inferior. A household is regarded to be fully resilient if all indicator variables remain unaffected. We apply principal component analysis (PCA) to aggregate the indicators into a drought resilience index (DRI) that serves as dependent variable in a regression model to identify its influencing factors. A substantial share of households was found to be fully resilient; hence, the distribution of the *DRI* is censored (compare Fig. 3), and an ordinary least squares regression would yield biased estimates. Therefore, we employ a model proposed by Tobin (1958) that accounts for the qualitative difference between limit and non-limit observations and uses the maximum likelihood (ML) method for parameter estimation. The 'Tobit' model expresses the observed outcome (DRI) in terms of an underlying latent variable as follows:

$$y_i^* = \beta_0 + \sum_{j=1}^{k} \beta_j x_{ij} + \varepsilon_i \tag{1a}$$

$$DRI_i = \min\left(y_i^*, 1\right) \tag{1b}$$

where

y^*=Latent dependent variable 'drought resilience'
i=Household index (i=1,...,N)
$\boldsymbol{x}_j$=Vector of explanatory variables (j=1,...,k)
$\boldsymbol{\beta}$=Vector of parameters to be estimated
ε=N (0, σ^2) distributed random error term
DRI=Observed dependent variable 'drought resilience index'

The latent dependent variable y* in Eq. 1a satisfies the classical linear model assumptions.[4]

3.4 Determinants of drought resilience

This section derives the explanatory components to be included in Eq. 1a. Modifying the conceptual framework employed by Webb and Harinarayan (1999), our analysis is based on the following functional relationship:

$$\text{DRI} = f(\text{Hazard, Risk management}) \tag{2}$$

Hazard and risk management are in turn functions of the following general formula:

$$\text{Hazard} = f(\text{Probability, Pressure, Predictability}) \tag{2a}$$

where

Probability = Probability of occurrence of a hazardous event
Pressure = Pressure exerted by the hazardous event, i.e., the intensity of impact
Predictability = Predictability of the hazardous event, i.e., the degree of warning available

[4]In particular, it has a normal, homoscedastic distribution with a linear conditional mean.

and

$$\text{Risk management } = f(\text{Asset base, Risk attitude}) \tag{2b}$$

According to the livelihoods resources pentangle, the asset base can be subdivided into natural, physical, financial, human, and social capital (Devereux 2003). However, a distinction between physical and financial resources is often difficult, especially if an asset is easily liquidated; we therefore adopt the classification proposed by Scoones (1998), which combines the two types to form a single category of 'economic and financial capital'. Apart from idiosyncratic factors a household's attitude toward risk also largely depends on its asset base (Morduch 1995). Because of this endogenous nature, we do not attempt to measure the risk attitude explicitly, but we assume it to be indirectly reflected by the household's asset base. We measure drought resilience in households that have already been exposed to drought; thus, the probability of drought does not enter our model. Combining the above structural equations into one, the following reduced-form model of determinants of drought resilience can be estimated:

$$\text{DRI } = f(\text{Pressure, Predictability, NC, EFC, HC, SC}) \tag{3}$$

where

NC = Natural capital
EFC = Economic and financial capital
HC = Human capital
SC = Social capital

4 The data and definition of variables

To account for the variation in local climatic conditions, eight out of the 53 villages located in the Palu River watershed were randomly selected using elevation above sea level as the stratification criterion. A stratified random sample of 228 farm households was then selected using locally available lists of households as sampling frame, which were based on the most recent village census. In January and February 2003 data were collected using structured interviews. To start with, the most severe drought period experienced by each household was identified, the remainder of the interview then referred to this event; in cases of several droughts of equal perceived severity, the most recent period was chosen in order to minimize recall bias. Applying this rule, 70% of the interviews were based on an ENSO-related drought in 2002, i.e., an event experienced only months prior to the survey. Only 8% of the interviews involved a recall period of more than 5 years. Moreover, the questionnaire was designed in such a way that different sections cross-checked the information gained concerning drought-induced yield declines, mitigation and coping measures, and differences in consumption between drought and non-drought periods.

Based on structural Eq. 3 the following paragraphs describe the explanatory variables included in the model of influencing factors of drought resilience in detail; brief definitions are summarized in Table 3 (Section 5).

As proxies for the pressure exerted by the drought in a particular location, we use the mean crop yield share a farmer obtained during the drought relative to a 'normal' year.[5] Furthermore, the variable *Forced fallow* captures those cases in which after the onset of the

[5]Based on plot-specific recall data and weighted by plot size; the natural logarithm of this variable enters the final model because heteroscedasticity was detected in the unlogged variable.

drought farmers decided not to plant a crop at all because crop failure was foreseeable. Regarding the predictability of a drought, a dummy variable on prior awareness of the likely occurrence of a drought is included in the model. Since this enables farmers to take precautionary measures, e.g. by adjusting planting dates or growing drought tolerant crops, it is expected to positively influence resilience.

Natural capital is reflected by the elevation of the cultivatable area above sea level and a soil fertility indicator. The remarkable dry-to-wet gradient between the coastal zone and the elevated inland areas (see Section 2) indicates that climatic conditions are relatively less conducive to crop growth in low-lying areas, thus weakening resilience. The predominant soil color of the cultivatable area is used as a proxy for its soil fertility status.

The category of 'economic and financial capital' encompasses the ownership of easily liquidated assets, off-farm income, and access to credit.[6]. The variable *Liquid assets* measures the total value of vehicles and agricultural implements as well as television sets, radios, and other household appliances; moreover, it encompasses the value of small animals owned. Data on off-farm income were obtained for the non-drought year 2001. Thus, the variable *Off-farm income* does not refer to alternative income sources tapped in response to the drought, but it is a proxy for regular off-farm income. *Maximum credit* is the respondent's assessment of the maximum amount of money the household could realistically borrow[7].

Human capital is reflected by the aggregate household labor capacity, educational status, and technical efficiency in agricultural production. The individual labor capacity is assumed to be closely related to the individual consumption requirements. Therefore, the number of household members converted into adult equivalents (see footnote 6) is used as a proxy for the aggregate household labor capacity: as a consequence of drought, mitigation and/or coping measures may involve old people as well as children, whereby children under 10 years of age were not included in the calculation. The level of formal education is expected to improve general risk management capabilities and the access to more profitable non-agricultural income opportunities. Technical efficiency (TE) in agricultural production reflects a farmer's know-how regarding crop management; technical inefficiency exists if for a given set of inputs and a given production technology a household fails to attain the maximum possible (frontier) output (Farrell 1957). For the two primary crops in the research area, irrigated rice and cocoa, separate frontier production functions were estimated by Keil (2004), and the level of TE was derived employing a model specified by Battese and Coelli (1995); mean TE in the cultivation of cocoa, a relatively new crop in the research area, was estimated to be merely 37%, as opposed to 77% in rice production (Keil 2004, p. 110). The potential for increased productivity through improved crop management is therefore particularly large in the case of cocoa. A high level of TE is hypothesized to enhance resilience by facilitating the accumulation of reserves during times of 'normal' climatic conditions that can be used to smooth consumption during drought.

Social capital is reflected by the number of organisations a household is involved in, which we hypothesize to be a proxy for the size of the social network at its disposal.

[6]Since, *ceteris paribus*, the impact of a drought on household food consumption and expenditure depends on the size of the household, the asset-related variables are converted to a per-capita basis where applicable. We assume individual food and expenditure requirements to be closely related to the physiological needs of the respective household member. Therefore, we transform the total number of household members into adult equivalents (AE) according to gender and age using the recommendations for caloric requirements developed by the WHO/FAO (1973).

[7]Following the methodology developed by Diagne et al. (2000).

Finally, following Battese (1997), the dummy variables *No assets*, *No off-farm income*, *No credit* and *No participation* correct for potential bias caused by 'zero-observations' in the variables *Liquid assets*, *Off-farm income*, *Maximum credit* and *Participation in organisations*.

5 Results

5.1 The risk of drought in Central Sulawesi

Out of the 228 sample households (HH), 188 (82%) have ever been negatively affected by an abnormally long dry period. According to the respondents, the most severe droughts occurred in 2002 (59% of cases) and 1997/98 (15%). On the average, the most severe drought experienced caused the yields of irrigated rice and cocoa to decline to 64 and 62% of their usual level, respectively. Six percent of the rice-growing HH suffered a complete loss of their crop. There is no statistically significant evidence that the reduced supply of either rice or cocoa led to an increase in farm gate prices, mitigating the impact of reduced yields on agricultural income. Based on a gross margin calculation that assumes constant prices and constant non-agricultural income, the drought-induced decline in crop yields caused a reduction of the annual income of the average farm household by approximately one third.

5.2 Household responses to the risk of drought

Fifty-five HH (24%) employ ex-ante mitigation strategies for the case of a drought, whereby the two most widely applied measures are the keeping of food stocks (62% of these HH) and cash savings (31%). Risk management is thus mostly confined to ex-post coping strategies: in order to smooth consumption despite their reduced agricultural income, 43% of the affected HH earned income from sources that are not usually utilized, the primary additional income sources being temporary employment (72%) and the sale of rattan collected in the adjacent Lore Lindu National Park (28%, multiple responses possible). Furthermore, 21% obtained a loan from informal sources such as traders and shopkeepers; on the average, the annual interest rate charged for consumption loans amounted to 64% and ranged up to 400%. Agricultural adaptation measures were comparatively scarcely practiced: 16% of HH changed the area share of different annual crops, e.g., they grew maize instead of rice, and 15% changed the amount of inputs applied to their crops. Hence, the majority of farmers followed a 'standard' crop management procedure without adjusting planting dates, crop area shares, or input supply in response to climatic conditions.

A total of 116 drought-affected HH (62%) were not able to maintain their usual level of consumption with respect to basic necessities: Fig. 2 provides an overview of the percentage of households that reduced different expenditure categories (fat bars); within each category, the thin bars show the mean level the respective expenditures were reduced to.

5.3 The 'drought resilience index'

Table 2 lists the definitions and summary statistics of the consumption and expenditure related indicators that the drought resilience index (DRI) is based upon. For example, it shows that, on the average, drought-affected households reduced food expenditures to 81% of the 'normal' level and decreased the monthly frequency of rice consumption by 13

Table 2 Expenditure and consumption related indicators used to construct a 'drought resilience index' (DRI) for farm households in Central Sulawesi[a]

Variable description	Mean	SD	Min	Max	Hypothesized relationship with DRI	Component loading
Share of expenditures during drought as compared to the 'normal' situation (%) with regard to						
Food	81.21	21.75	20.00	100.00	+	0.844
Clothing	70.15	35.35	0.00	100.00	+	0.837
Housing	63.43	44.11	0.00	100.00	+	0.786
Social events	83.99	25.57	0.00	100.00	+	0.744
Health	88.43	24.07	0.00	100.00	+	0.582
Difference in monthly consumption frequencies between the 'normal' and the drought situation with regard to						
Rice	13.04	20.58	0.00	90.00	−	−0.703
Maize	−5.46	14.51	−90.00	8.60	+	0.549
Beef	0.12	0.33	0.00	1.00	−	−0.438
Chicken	0.24	0.52	0.00	4.30	−	−0.412

[a] Statistics are based on 188 households whose agricultural production was negatively affected by drought.

servings per person[8]. Furthermore, the table contains the indicators' hypothesized direction of relationship with the *DRI* and their component loadings derived by PCA; all signs of the component loadings conform to our expectations. Only indicators with an absolute loading greater than 0.4 were retained in the final model, as suggested by Stevens (2002, p. 394).

The Kaiser–Meyer–Olkin measure of sampling adequacy yields a value of 0.76, indicating a distinct and reliable first component. Because of the size of its Eigenvalue and the size and signs of its component loadings as compared to those of further components extracted, we conclude that the first principal component, which explains 45.3% of the total variance in the data, is the one reflecting drought resilience. The households' scores on this factor, which have a mean of zero and a standard deviation of one, were converted to the $DRI \in [0,1]$. Figure 3 displays its cumulative distribution function; its maximum value is attained by those 72 drought-affected households (38%) that were capable of smoothing consumption.

5.4 Determinants of drought resilience

Table 3 lists the variables in the Tobit regression model and their summary statistics. Only 162 out of 188 drought-affected households were included because of missing values in the variables *Yield share* (some farmers did not grow any crops during the drought) and *Technical efficiency* (not all of the farmers grow rice and/or cocoa). Table 4 presents the ML estimates of the coefficients of the explanatory variables.[9]

[8]Regarding the intra-household distribution of the reduced amount of food available, no significant differences were found between male and female household members and age groups.

[9]The parameter estimates relate to the normally distributed latent dependent variable y^* (drought resilience), which is the actual variable of interest, rather than the observed variable *DRI* whose share of censored observations depends on the severity of the drought experienced. The partial effects with respect to the censored dependent variable *DRI* can be derived by multiplying the Tobit estimates with the scale factor 0.6695. This adjustment factor depends on the values of all explanatory variables and parameters, but it does not change the interpretation of the results since *DRI* is a relative measure of drought resilience among the sample households.

Table 3 Hypothesized influencing factors of household (HH) drought resilience in Central Sulawesi, and their summary statistics[a] (hypothesized direction of relationship in parentheses)

		Variable description	Mean	SD
Dependent variable				
DRI	=	Drought resilience index	0.75	0.28
Hazard proxies				
Yield share (+)	=	Logged mean percentage share of normal yield during drought, weighted by plot size[b]	58.89	25.44
Forced fallow (−)	=	Dummy, =1 if at least one crop could not be planted due to drought, 0 otherwise	0.06	0.23
Predictability proxy				
Prior information (+)	=	Dummy, =1 if HH had prior knowledge of the likely occurrence of a drought, 0 otherwise	0.10	0.30
Natural capital				
Low elevation (−)	=	Dummy, =1 if elevation of village<100 m above sea level, 0 otherwise	0.43	0.50
Poor soil (−)	=	Dummy, =1 if the predominant soil color is reddish/yellowish, 0 if it is black/brown	0.24	0.43
Economic/financial capital				
Liquid assets (+)	=	Value of liquid assets per AE[c] (100,000 IDR[d])	5.19	7.92
Off-farm income (+)	=	Regular off-farm income per AE (100,000 IDR)	3.63	6.65
Maximum credit (+)	=	Maximum amount of credit available per AE (100,000 IDR)	2.46	7.44
Human capital				
Labor capacity (+)	=	Aggregate HH labor capacity in AE, excluding children <10 years of age	3.38	1.44
Education (+)	=	Number of years of formal education of the most educated HH member	8.75	2.76
Technical efficiency (+)	=	Mean technical efficiency in rice and/or cocoa cultivation, weighted by area share	0.63	0.23
Social capital				
Participation in organisations (+)	=	Number of organisations the HH is involved in	1.62	1.58
Dummy variables correcting for zero-observations in explanatory variables				
No assets (−)	=	Dummy, =1 if value of 'liquid assets' is zero, 0 otherwise	0.07	0.25
No off-farm income (−)	=	Dummy, =1 if value of 'Off-farm income' is zero, 0 otherwise	0.37	0.48
No credit (−)	=	Dummy, =1 if value of 'Maximum credit' is zero, 0 otherwise	0.07	0.26
No participation (−)	=	Dummy, =1 if value of 'participation in organisations' is zero, 0 otherwise	0.36	0.48

[a] Summary statistics are based on 162 cases without missing values for any of the variables.

[b] For ease of interpretation, summary statistics are given for the unlogged variable.

[c] Adult equivalents based on caloric requirements, differentiated by gender and age (WHO/FAO 1973).

[d] Indonesian Rupiah. 1 US$=8,900 IDR (February 2003).

Table 4 Maximum likelihood estimates of influencing factors of household drought resilience in Central Sulawesi (N=162)

Variable	Coefficient[a]	t value[b]	Mean	VIF[c]
Constant	−0.2943	−1.55		
Yield share	0.1163	5.19***	3.864	1.21
Forced fallow	−0.3261	−3.30***	0.056	1.19
Prior information	−0.1075	−1.34	0.099	1.21
Low elevation	−0.1234	−1.95*	0.432	1.42
Poor soil	0.0474	0.67	0.241	1.12
Liquid assets	0.0162	3.73***	5.186	1.24
Off-farm income	−0.0045	−1.40	3.634	1.39
Maximum credit	0.0134	2.29**	2.457	1.13
Labor capacity	0.0552	2.51**	3.382	1.20
Education	0.0112	0.97	8.750	1.37
Technical efficiency	0.4036	2.99***	0.627	1.23
Participation in organisations	0.0673	1.95*	1.617	3.18
No assets	−0.0791	−0.82	0.068	1.23
No off-farm income	−0.0910	−1.39	0.370	1.41
No credit	0.0135	0.13	0.074	1.13
No participation	0.1810	1.83*	0.364	2.80

LR χ^2=65.17***
Log likelihood=−74.104
Pseudo R^2=0.305
Sigma=0.324***
% censored observations (upper limit)=40.1

*(**)[***] Statistically significant at the 10% (5%) [1%] level of eror probability.

[a] Dependent variable: drought resilience index. Parameter estimates are based on a Tobit regression.

[b] t Values are based on the heteroscedasticity-consistent standard errors proposed by White (1980).

[c] Variance inflation factor

6 Discussion

6.1 The risk of drought and farmers' responses

The vast majority of sample households have experienced drastic drought-induced declines in crop yields, which are not significantly mitigated by local price effects. In the case of rice, the lack of price effects may be explained by the heterogeneity of both climatic conditions and irrigation facilities within the research area, allowing localized drastic reductions in rice supply to be relatively easily compensated; in the case of the primary cash crop cocoa, prices are, of course, largely determined by world market conditions. Not accounting for income-smoothing ex-ante or ex-post strategies, the yield depressions translate into a reduction of total annual household income by one third, on the average. These findings are in line with other studies conducted in Indonesia, such as Salafsky (1994), Harger (1995), and Amien et al. (1996). Contrary to Naylor et al. (2001) and Falcon et al. (2004) who found that El Niño affected rice production in Java and other major rice-growing areas of Indonesia mainly through a reduction in the area harvested rather than a decline in yields, we find that the opposite is the case in Central Sulawesi: here, most farmers followed their 'standard' crop management procedure both in 'normal' and drought seasons, resulting in reduced yields during the latter. The reason for this discrepancy in findings may be that the majority of farmers in Central Sulawesi rely on non-technical irrigation facilities with an irregular water supply, and that a coordination of the cropping and irrigation schedule at the village level is often lacking or malfunctioning.

Most of the affected respondents mentioned the year 2002 as the most severe drought year experienced, followed by the period 1997/98. Both drought periods were related to El Niño. However, the Southern Oscillation index (SOI) suggests that the 1997/98 drought was more severe than the 2002 drought (NOAA 2005). Hence, in their assessment of drought severity, the respondents may have been biased towards the most recent drought experienced. This does not compromise the validity of the *DRI*, though; on the contrary, the fact that most interviews were based on the very recent 2002 drought (see Section 4) implies a relatively high level of data quality.

In spite of the substantial risk of drought, less than one quarter of the sample households employ ex-ante mitigation measures. The most common ex-post strategy to smooth consumption is the tapping of income sources that are not usually utilized, including the sale of rattan from the adjacent Lore Lindu National Park, which is prohibited. The extraction of rattan not only implies a loss of biodiversity in the surrounding rainforest, but it also means that a substantial share of farm households resorts to an illegal activity in order to cope with the consequences of drought. El Niño-related coping strategies that threaten forest resources are also reported from the Philippines by Monsalud et al. (2003). One fifth of our sample households obtained an informal loan to smooth consumption; the high interest rates charged imply that the use of informal credit bears the risk of becoming indebted and may therefore contribute to trapping households in poverty. Real interest rates in excess of 100% for informal consumption credit are confirmed by Zeller et al. (1997, p. 22).

In consequence of the drought, 62% of households were not able to maintain their usual level of expenditures, whereby all the major basic needs domains, i.e., food, clothing, housing, and health were affected. It is particularly alarming that 85% of the households that reduced expenditures did so in the food sector, and that, on the average, they reduced food expenditures to merely 64% of their usual level. Both the quantity and quality of food were cut back: 30% of these households were forced to eat less than three meals per day, and all of the households cut down on the consumption of protein-rich foods such as fish and meat. Thus, droughts have a substantial impact on the nutritional status of the affected farm households.

6.2 Drought resilience and its influencing factors

All of the test statistics related to the *DRI* indicate that for our data set Principal Component Analysis is an appropriate method for the construction of an index. Based on the set of selected expenditure and food consumption-related variables, the first extracted factor is clearly the one reflecting household drought resilience. Figure 3 shows that the *DRI* differentiates well among the households that were not able to maintain their usual level of expenditures for basic necessities because of the drought. Since the *DRI* is a relative measure of drought resilience within our sample, an interpretation of the absolute values of the coefficients in the regression model is not informative. We will therefore confine our discussion to the sign of the coefficients and their relative size if the associated variables are based on the same scale.

The variables *Yield share* and *Forced fallow* correct for differences between individual households regarding the pressure exerted by the most severe drought experienced. The

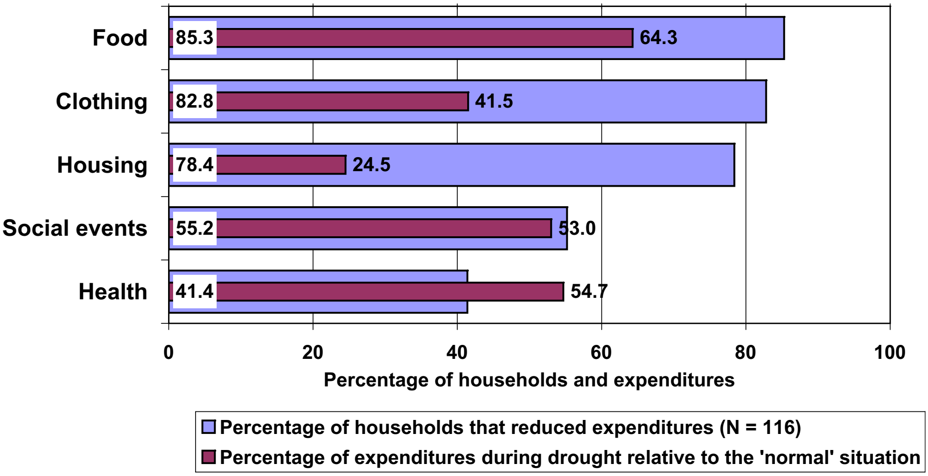

Fig. 2 Reduction of household expenditures as a reaction to decreased agricultural income due to drought in Central Sulawesi

higher the mean share of crop yields during the drought as compared to the 'normal' situation, the less pronounced the negative impact on the respective household. Not being able to plant one or more crops due to the drought has a substantial negative effect on household expenditures and consumption. No effect of prior knowledge of the likely incidence of a drought on household resilience is supported by the data. Only 16 farmers (10%) said that they were informed about the likely event of the drought; but, on the average, this happened only 2.5 months before the onset of the drought, which may have been insufficient for the implementation of effective mitigation measures. Moreover, the reliability of the source of information has to be taken into account since this will affect the

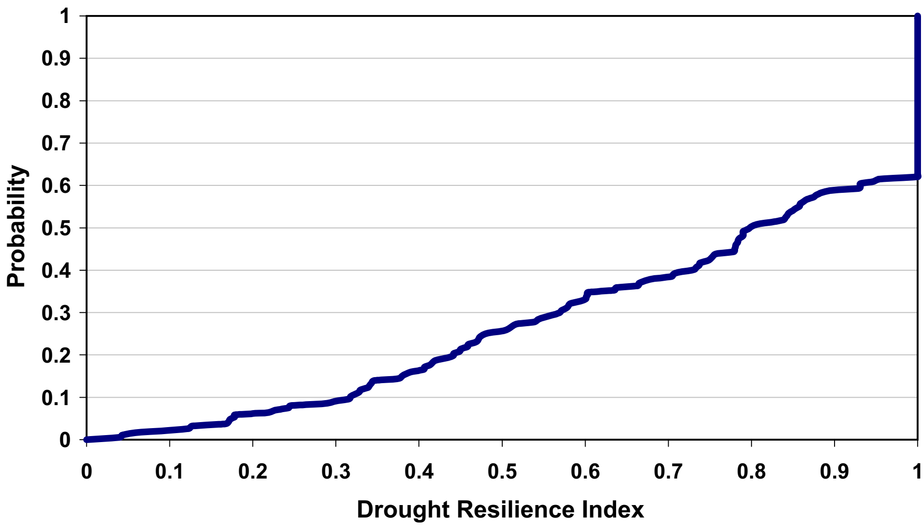

Fig. 3 Cumulative distribution function of the 'drought resilience index' (DRI) for farm households in Central Sulawesi (N=188)

expected return associated with a mitigation measure and, hence, influence the decision whether to implement it or not. For example, 'erroneously' growing soybeans instead of rice in expectation of a drought will incur opportunity costs in terms of revenue foregone if rice is the more profitable crop under normal conditions. Eight farmers based their knowledge on an 'official' source of information, i.e., radio, television, or the agricultural extension service; the remaining eight farmers used indigenous knowledge. Which of the two types of information is more reliable at the local level is, of course, debatable; Falcon et al. (2004) found that Central Sulawesi was one of the few provinces in Indonesia where their simple ENSO forecast model did not perform well with regard to rice production.

As elaborated in Section 4, the significant negative coefficient of the dummy variable *Low elevation* confirms our hypothesis that the particularly dry conditions found at low elevations in the research area negatively affect crop growth in general. *Ceteris paribus*, the relatively low land productivity reduces agricultural income as compared to climatically more favorable locations, thus reducing household resilience. Contrary to the case of our research area, Bang and Sitango (2003) found that upland regions had more pronounced decreases in rainfall during El Niño than lowland areas, which emphasizes the relevance of the local topography. The sign of the coefficient of the soil fertility proxy is contrary to our expectations, but it is not significantly different from zero. One reason for its unexpected sign may be that the use of mineral fertilizer is not taken into account: on the one hand, the use of fertilizer may compensate for a poor natural soil fertility status, whereas on the other hand fertilizer use is often low or non-existent on recently slashed-and-burned plots of relatively high natural fertility.

Differences in the type of irrigation facilities available are captured by the hazard proxy variable *Yield share*. Descriptive data analysis shows that the drought-induced decline in rice yields is less pronounced on land with technical irrigation as compared to land with less effective irrigation facilities.

As expected, the possession of easily liquidated assets, and access to credit have a positive impact on household resilience. Since the two variables are based on the same scale and the coefficient of *Liquid assets* is approximately 21% larger than that of *Maximum credit*, we can further conclude that one monetary unit of liquid assets has a greater effect on drought resilience than one unit of available credit line. This is understandable since the interest and transaction costs of credit are likely to be considerably higher than the transaction costs involved in the sale of liquid assets. However, it has to be kept in mind that both variables are indicators of the general wealth status of the household, showing that the consumption patterns of wealthier households are less severely affected by drought than those of poorer households. Relatively wealthy households may not even need to sell any liquid assets or make use of their capacity to borrow money in order to smooth consumption during drought.

No influence of regular off-farm income is supported by the data. Fifty-one percent of the sample households earn wage labor income, whereby in two thirds of these cases income is derived from employment in agriculture, usually in the same or a neighboring village. Hence, wage labor income is directly affected by drought in most cases. Nineteen percent of households generate non-agricultural income through self-employment. In 37% of these cases households run a local kiosk, and the goods and services provided by the remaining households are also marketed at a local level. Therefore, when the local agricultural income declines due to drought, the demand for these goods and services is likely to decrease, thus negatively affecting non-agricultural income as well. This is in line with Fafchamps et al. (1998) who found that, due to a collapse of the demand for local services and crafts, droughts adversely affected not only crop income but also off-farm income in West Africa.

As far as human capital is concerned, the aggregate household labor capacity and the average level of technical efficiency (TE) in the cultivation of rice and cocoa are resilience enhancing factors, which confirms our hypothesis as explained in Section 4. The data do not support a positive influence of the maximum level of formal education within a household. Rather, the combined household labor capacity, which is a prerequisite to the implementation of labor-intensive coping measures, and the qualification of the household concerning proper crop management are of relevance.

Finally, we find that the number of village organizations a household is involved in positively influences its resilience. This confirms our hypothesis that households are able to benefit from an extensive social network during crises. The statistically significant positive coefficient of the related zero-observation dummy variable *No participation* is surprising. It implies that those households that do not participate in official village organizations have other types of informal social networks at their disposal.

7 Conclusions and policy recommendations

In summary, our results lead to the following conclusions: Despite the location in a rainforest area, farmers in Central Sulawesi face a substantial risk of recurring, El Niño-related drought periods entailing significant income depressions. Although ENSO forecasts are generally available in Indonesia, most of the farmers in the research area do not have access to this information; moreover, there is evidence that ENSO effects on agricultural production in this mountainous area are more difficult to predict than in many other parts of Indonesia. Hence, farm households' level of preparedness for the case of drought is generally low, so that risk management is usually confined to ex-post coping strategies. These include environmentally damaging and illegal activities, as well as other strategies that may threaten future welfare. In spite of the mitigation and coping measures employed, the majority of the affected farm households have to cut expenditures to adapt to the drought-induced reduction of agricultural income; the drastic cuts in food expenditures are particularly alarming, suggesting that droughts seriously impair the nutritional status of farm households in the area.

Household drought resilience is positively influenced by the possession of assets which can easily be liquidated in the case of drought, as well as by access to credit. Furthermore, a high level of technical efficiency in agricultural production, i.e., the ability to make optimum use of inputs through skillful crop management, is a resilience enhancing factor: it increases agricultural income at least during years of average climatic conditions and therefore facilitates the accumulation of assets and savings that can then be used to smooth consumption during drought or other crisis periods. Particularly large increases in production through improved management would be possible in the cultivation of cocoa, the primary cash crop in the research area.

From these findings, several policy recommendations and suggestions for future research can be deduced. First, improved access to ENSO forecasts in the research area would give farmers a better chance of taking precautions before the onset of a drought. Here, a particular research challenge lies in the development of climate models with acceptable levels of accuracy for mountainous regions like Central Sulawesi. However, even access to a more general ENSO warning system would at least sensitize farmers, and they may then be able to judge from experience whether they are likely to be affected by drought conditions in their particular location. This information could be disseminated through mass media as well as via the agricultural extension service. Second, in the context of potential mitigation measures, future research should investigate the agronomic and marketing potential of relatively drought tolerant crops, such as peanuts, in the research area. Third, the creation of formal financial institutions at the village level should be fostered: on the one hand, there is a high demand for consumption credit during crisis periods which may lead into a poverty trap through exorbitant interest rates charged by informal lenders. On the other hand, there is a need for savings options which are less prone to depreciation than the common practice of accumulating food stocks. And, fourth, in order to enhance the low levels of efficiency currently found in agricultural production, extension efforts should be intensified, emphasizing the proper management of cocoa above all. The latter two policy recommendations aim at strengthening the asset base and, hence, self-insurance capacity of farm households; thus, they have the potential to enhance household drought resilience even if no specific drought mitigation measures are employed, at the same time contributing to poverty alleviation in the long run.

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