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THE IMPACT OF ENSO (EL NIÑO - SOUTHERN OSCILLATION) ON SUSTAINABLE WATER MANAGEMENT AND THE DECISION-MAKING COMMUNITY AT A RAINFOREST MARGIN IN INDONESIA (IMPENSO)

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1 Summary

The IMPENSO project deals with the impact of the climate variability ENSO (El Niño Southern Oscillation) on water resource management and the local communities in the Palu River watershed of Central Sulawesi, Indonesia. The project consists of three interrelated sub-projects, which study the local and regional manifestation of ENSO using the Regional Climate Models REMO and GESIMA (Sub-project A), quantify the impact of ENSO on the availability of water for agriculture and other uses, using the distributed hydrological model WaSiM-ETH (Sub-project B), and analyze the socio-economic impact and the policy implications of ENSO on the basis of a production function analysis, a household vulnerability analysis, and a linear programming model (Sub-project C). The models used in the three sub-projects will be integrated to simulate joint scenarios that are defined in collaboration with local stakeholders and are relevant for the design of coping strategies.

2 Aim of the Research in the Framework of DEKLIM

Within DEKLIM, the Climate Impact Research program DEKLIM C focuses on the interaction between climate change or variability, natural systems, and socio-economic systems. Taking a rainforest margin area in Central Sulawesi, Indonesia, as an example, the IMPENSO project analyzes the impact of the climate variability caused by ENSO (El Niño - Southern Oscillation) on water resources and the local communities. ENSO-related climate variation is widely considered to be the largest global periodic climate signal after the seasonal cycle. In South-East Asia, ENSO aggravates the socio-economic and environmental problems caused by increasing population pressure on fragile agro-ecological zones. To identify appropriate policies to cope with the impact of ENSO, there is a need for interdisciplinary studies which (1) are based on bio-physical and socio-economic data and models on the meso-and micro-scale, and (2) include - in a participatory approach - the perceptions, reactions and adaptation strategies of rural households and local communities.

The research area of the IMPENSO project (see Appendix), the watershed of the Palu River in Central Sulawesi, Indonesia, is well suited for this type of research. It forms part of the research area of our partner project STORMA (www.storma.de), which allows for an extensive exchange of data. The watershed covers an area of 2694 km². The region is characterized by a very high biophysical and socio-economic diversity. The coastal region around Palu with four to six arid months and an annual precipitation of only 600 mm belongs to the driest regions of Indonesia. This climatic feature changes dramatically when approaching the nearby mountain regions where precipitation increases up to more then 2000 mm per year. The Gumbasa River sub-basin (1308 km²) serves as a major water supply of the important rice growing areas of the Palu valley. More than half of the area (898 km²) of the Gumbasa sub-basin is covered by the northern part of the Lore Lindu National Park (2396 km²), protecting a stable water supply for the Gumbasa irrigation scheme. The population of the research region comprises approx. 30,000 people. The ethnic diversity of the indigenous population has been increased by rapid in-migration. The rural areas are characterized by a high incidence of poverty and the population mostly relies on agricultural production. Especially low precipitation rates during ENSO events considerably reduce the productivity of the farming systems.

Taking the Palu River watershed as an example, the **overall objective** of IMPENSO is to quantify the local and regional manifestations of global climate variability, analyze their implications for water resources and agricultural land use, and assess their socio-economic impact on rural communities living in agro-ecologically sensitive regions. To fulfill this overall objective, the project consists of three interrelated sub-projects that have the following **specific objectives**:

Sub-project A on "Climate Variability and ENSO" has the objectives to

- analyze the precipitation variability and regional distribution patterns based on the local registration network and regional data, and to regionalize climate parameters considering the results obtained from measurements by IMPENSO and STORMA,
- verify the numerical results of the large-scale general circulation model of the European Centre for Mediumrange Forecast (ECMWF), and nest with the regional hydrostatic climate model REMO,
- down-scale the REMO model to resolve the effect of the quite heterogeneous region of the Palu area on a small time and space scale with the non-hydrostatic meso-scale numeric model GESIMA in order to calculate evapotranspiration and precipitation rates on a 1 km grid scale level, to compare these rates with measurements, and to integrate them in the soil and water budget model of sub-project B, and
- to predict with the nested ECMWF model for a time scale of several months the atmospheric conditions and soil water content in the Palu area.

Sub-project B on "Impact on the Water Budget" has the objectives to

- install further river stage recorders and climate stations to enhance the network of observed data,
- preprocess spatial data (DEM, geology, soil types, vegetation classification) for the hydrological model,
- apply the distributed hydrological model WaSiM-ETH and integrate regionalized climatic parameters provided by sub-project A within the hydrological model,
- assess the impact of climate variability and land use change on the water budget, and
- simulate climate and land use scenarios with the validated hydrological model concerning future trends in water availability, which will be integrated with sub-project C.

Sub-project C on "Socio-Economic and Policy Implications" has the objectives to

- apply participatory research methods to assess the perceptions, the knowledge and the explicit and implicit coping strategies of the local population with regard to ENSO,
- interview a stratified random sample of farm households in the Palu watershed in order to assess the impact of ENSO on the plot and farm household level,
- perform a production function analysis that makes it possible to quantify the impact of ENSO-related climate variability on the yields of the major crops in the research region,
- perform a household vulnerability analysis and develop a linear programming model to simulate farm household decision-making, and

- combine the use of the simulation model with participatory methods involving local groups and policy makers in order to derive policy recommendations.

The integration of the three research components is promoted by a close coordination of the research activities and the combination of the models of the three sub-projects for the **simulation of joint scenarios** that will be discussed with users and stakeholders. The following sections outline for each sub-project the recent and completed activities, the principal results, the main conclusions and the planned activities. This report covers the first two years of the project, which is planned for a time span of five years.

3 Activities and Results of Sub-project A

3.1 Recent and Completed Activities of Sub-project A

Atmospheric data, mainly of precipitation, for Sulawesi Island were collected from different agencies and analyzed. Thus, an overview of the climate conditions of the IMPENSO research area was obtained. For model validation purposes, the measured data were interpolated into grid data according to the model resolution. The atmospheric model that has been implemented is the Regional Climate Model ReMo with 1/6° resolution. Input data for running ReMo 1/6° come from the output of the same model, but at ½° resolution developed by the Max Planck Institute of Meteorology, Hamburg. ReMo ½° uses input data from ECMWF (European Centre for Medium-Range Weather Forecasts) Re Analyses (ERA data - ECMWF Re Analyses). The atmospheric simulation has been completed for the period from 1979 to mid 2000. Input data for the remaining years are being prepared. The precipitation rate, as an important atmospheric parameter in the tropics, has been measured and modeled for Central Sulawesi, including the IMPENSO research area. This model simulation has been used to study the impact of ENSO on the variability of the precipitation rate within Central Sulawesi.

3.2 Principal results of Sub-project A

The precipitation rates measured and modeled for the IMPENSO research area and the South Sulawesi sub-domain are shown in Figure 1. These two sub-domains have a different topographic situation. The precipitation simulation of ReMo 1/6° is in good agreement with reality in a quite flat area, as in the South Sulawesi sub-domain. For the IMPENSO research area, a lower correlation was found, probably due to the quite heterogeneous topography and, therefore, to the quite structured precipitation distribution. The model can explain the ENSO impact on the precipitation decrease during the El Niño years 1982/83, 1986/87, 1991 and 1993. The precipitation observations from individual locations within the IMPENSO research area (Kulawi) also show the ENSO impact (Figure 2). The Southern Oscillation Index (SOI) indicates strong ENSO events in 1987 and 1997. The average of the ENSO impact in several La Nina and El Niño years in the Kulawi region is shown in Figure 3. The main difference occurs during the dry season (July – October).

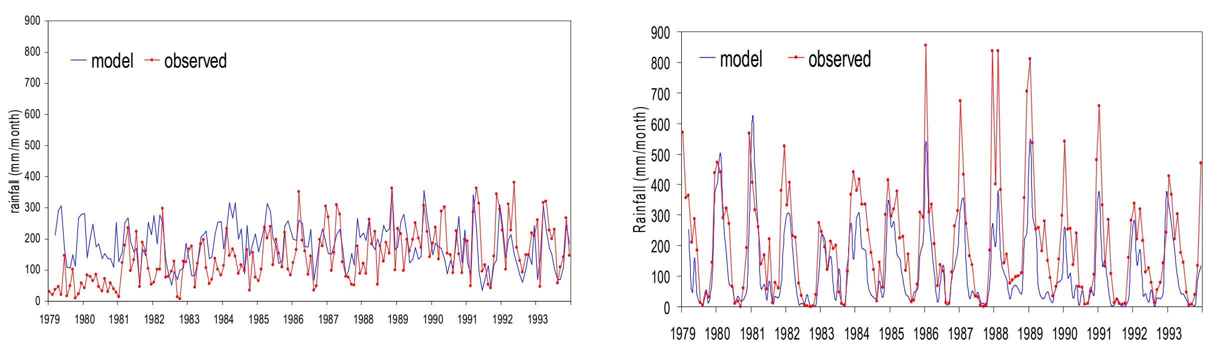

Figure 1. REMO 1/6° model validation for IMPENSO research area (left panel) and South Sulawesi sub-domain

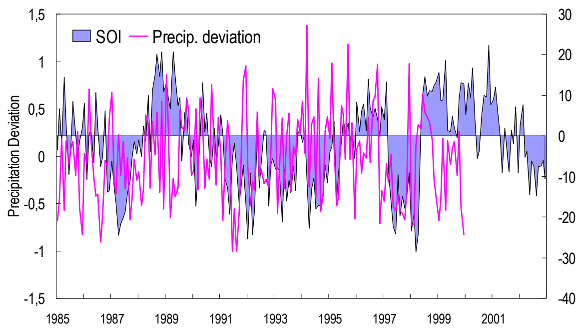

Figure 2. Monthly precipitation deviation in Kulawi, and the Southern Oscillation Index (SOI).

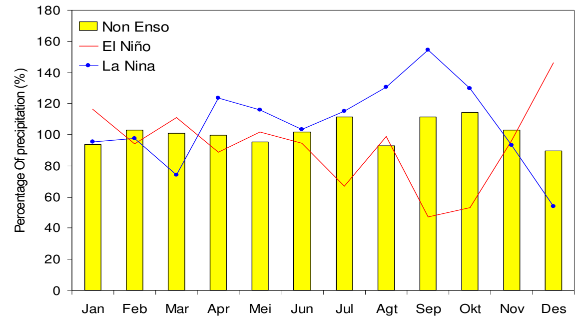

Figure 3. Percentage of monthly mean precipitation in Kulawi for different ENSO situation (El Niño, La Niña, Non-ENSO years).

The atmospheric circulation corresponding to the ENSO phenomenon is a zonal circulation (a Walker circulation). Figure 4 shows the modeled zonal wind component over the IMPENSO research area, near the surface (500 m above sea level/a.s.l) and at the upper troposphere of 11,000 m a.s.l. The wind circulation is westerly (positive) at 500 m a.s.l., and easterly (negative) at 11,000 m a.s.l. During the El Niño events, as in the years 1983, 1987, 1992, 1994 and 1998, the wind circulation at 500 m a.s.l comes from the east (filled area in Figure 4).

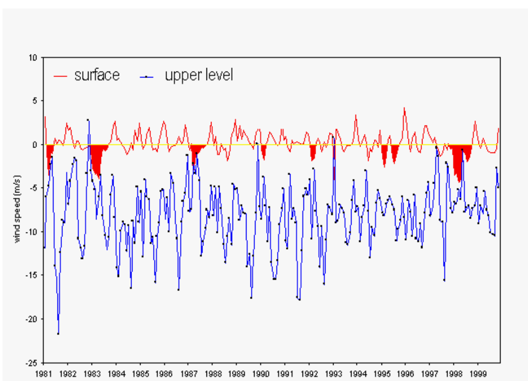

Figure 4. Modeled zonal wind component over IMPENSO research area. Negative values indicate an eastern wind, positive and western origin. Filled areas for the surface wind curve refer to El Niño events.

3.3 Planned Activities of Sub-project A

The nesting of the regional model ReMo with the local model GESIMA will be continued and finalized. A major task will be to parameterize the atmospheric physical processes on a smaller spatial scale than in ReMo and to develop the numerical interface between the ReMo and GESIMA models. The small-scale model GESIMA will determine the precipitation in the model area on local spatial scales. The model results will be compared with field measurements, part of which are done by sub-project B. Long term forecast of precipitation in the future (both half-year and 50 years scenarios) will be conducted with the atmospheric-ocean coupled ECHAM model, so that El Niño– La Niña events at increasing CO_2 concentration will be included in our analysis. The half-year forecast model runs of the coarse general circulation model ECMWF will be nested with ReMo-GESIMA in order to compare the regional-local precipitation half-year forecast with the reality measured in the field. The results will be used by sub-project B to assess the catchments' water budgets, which will enter into the farmer's decision-model developed by sub-project C.

4 Activities and Results of Sub-Project B

4.1 Recent and Completed Activities of Sub-project B

In order to evaluate the availability of input and calibration data for the set up of a meso-scale distributed hydrological model of the Palu River watershed, hydrological and meteorological data was collected from different state agencies. Due to the existing fragmentary data source of discharge and distributed rainfall data, a new hydrological network of 6 automatic stage recorders was set up (Appendix). To calculate stage - discharge rating curves of the selected gauging sites, we launched a flow velocity measurement campaign of the river profiles of the gauging stations, using the velocity – area method. In order to establish a significant rainfall regionalization for the region, eight additional IMPENSO climate stations have been added to the ten STORMA – project stations existing since 2001 (Appendix). The set-up of the climate stations was done in close cooperation with Subproject A (technical support, location, integration within STORMA network) and Subproject C (match with the selected eight research villages, socialization with villagers). According to a sensitivity analysis of other catchment studies, well-distributed rainfall measurements and statistically significant stage-discharge rating curves are a main task to improve hydrological model performance. We trained local scientific assistants for the maintenance of the hydrological and climatological stations and to further proceed with regular flow velocity measurements. Simultaneously distributed data of the physical properties of the catchment have been collected, evaluated, and if necessary converted into a digital format. This data source of the DEM (digital elevation model), soil types, geology and vegetation type classification is organized with a GIS, which serves as a basis to determine the parameter values required for the hydrological model of the watershed. Based on the DEM, we calculated important spatial hydrologic information like flow directions, flow accumulations, the river network and the sub-basin structure.

4.2 Principal results of Sub-project B

As indicated by Sub-projekt A the IMPENSO research area is characterized by a structured rainfall distribution due to its heterogeneous topography. Figure 5 shows the variability of the total precipitation for the first six months rainfall measurements of the IMPENSO and the STORMA climate stations which are situated within the IMPENSO research area. According to this distributed net of climate stations a rainfall regionalization will be performed, which serves as important input data for the performance of the distributed hydrological model.

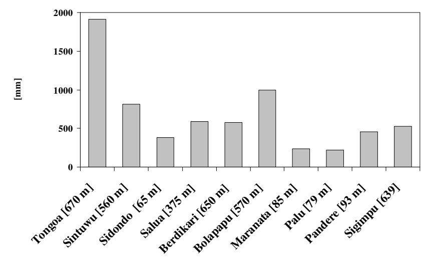

Figure 5. Total precipitation at IMPENSO / STORMA stations, September 2002 – March 2003.

River systems are enclosed integrators of rainfall over large areas. Hence, the river discharge can serve as an indicator for rainfall anomalies. Streamflow data of the Palu River sub-catchment Wuno River (190 km²) demonstrate the influence of ENSO on the hydrological cycle of the sub-catchment.

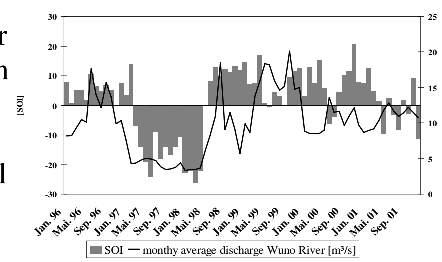

Figure 6. Correlation between the SOI index and the monthly average streamflow of the Wuno River 1996 – 2001.

ENSO years in Central Sulawesi are characterized by reduced rainfall during the dry season from August till November. These extreme events of drought closely correlate with a below normal streamflow (Figure 6). The ENSO Index SOI and the monthly average streamflow show a positive correlation index of 0.55 (Figure 6). Particularly the below normal streamflow event 1997 / 98 is described by the correlation. The analysis of the monitored stage data (September 2002 – March 2003) indicates a seasonal streamflow behavior with a reduced streamflow during the dry period from September till beginning of November (Figure 7). A comparison of the measured stage data from different sub- catchments demonstrates the influence of hydrological characteristics and recent land use to the response of the hydrological system to rainfall anomalies. The lake catchment shows a balanced hydrograph due to the high retention capacity of lake Lindu and the surrounding primary forest (Figure 7), whereas the hydrograph of the Takkelemo catchment (Figure 8) describes a high amplitude with peaks of flash floods.

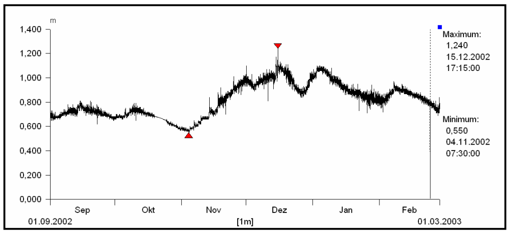

Figure 7. Observed stage (10 min res.) Rawa

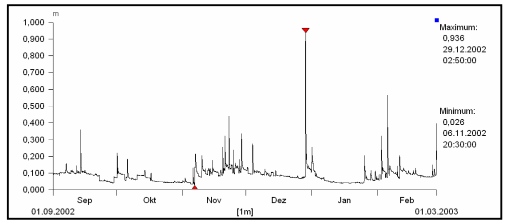

Figure 8. Observed stage (10 min res.) Takkelemo.

4.3 Planned activities of Sub-Project B

A major objective of future activities is the continuous monitoring of an at least two years time series of streamflow and precipitation data. The distributed hydrological model WASIM-ETH (Topmodel approach) will be applied to the Gumbasa sub-basin (1308 km²). The Gumbasa sub-basin (Appendix) represents the water resources catchment of the main irrigation scheme, which irrigates approx. 1000 ha of paddy fields along the Palu valley. By minimizing the model area on this sub-basin, we will be able to simulate the total amount of available irrigation water for the main irrigation scheme and at the same time exclude the complicated technical irrigation facilities from the distributed model. The calibration data time series will cover the first year and the validation data time series the second year of this monitoring data set. The current task is the preprocessing of the needed spatial data and further the parameterization of soil physical and vegetation properties with respect to a tropical catchment. By autumn 2004, the calibrated hydrological model of the sub-basin can be validated with the data set of the second monitoring year. Then the precipitation pattern of ENSO scenarios, which are preformed by the small scale climate model GESIMA of subproject A, will be applied to the hydrological model to quantify the effect of ENSO events on water resources, which then will be used for the joint scenario simulation model.

5 Activities and Results of Sub-Project C

5.1 Recent and Completed Activities of Sub-Project C

For modeling the impact of climate variability on yields, it was decided to apply stochastic frontier production functions using Translog or Cobb-Douglas functional forms, since these models can accommodate technical inefficiency as well as random yield variations. It was further decided to measure household vulnerability to climate variability using consumption and expenditure related indicators. Data were collected in eight randomly selected villages within the Palu River watershed, stratified by elevation. We conducted Rapid Rural Appraisals (RRAs) in all research villages, during which farmers discussed issues related to climate variability. Using the RRA results, a detailed questionnaire for the household survey was designed and tested. A total of 228 randomly selected farm households in the research villages were surveyed, whereby a major share of sample households was identical with those interviewed by the STORMA research project (SFB 552). Hence, research funds could be used more efficiently by using already existing data on general farm and household characteristics. Preliminary results were presented to local stakeholders and distributed to the heads of the research villages. In Göttingen, the descriptive analysis of the household data was completed. The production function analysis is currently ongoing.

Table 1. Perceived length and severity of drought periods experienced, differentiated by sub-district

Sub-district	N	Length of drought period experienced (months)*		Severity score of drought period (0 = no impact on HH, …, 5 = very serious negative impact on HH)*	
		Most severe	2002	Most severe	2002
Sigi Biromaru	93	5.16 [a]	4.15 [a]	3.56 [a]	2.88 [a]
Kulawi	77	4.38 [b]	3.79 [a]	3.07 [a]	2.64 [a]
Palolo	58	3.16 [c]	1.97 [b]	2.17 [b]	1.28 [b]
Total	228	4.39	3.48	3.05	2.40

*Homogeneous subsets (a, b, c) based on Student Newman Keuls Test, $P < 0.01$
If no drought was experienced: Length and severity = 0
Source: Own data

5.2 Principal results of Sub-project C

The descriptive analysis of the data showed that 93 % of the sample households (HHs) have experienced at least one abnormally long dry period since they have been living in their respective village. The most severe droughts occurred in 2002 (according to 58.5% of respondents) and 1997/98 (14.6%). Both are acknowledged to have been times of ENSO events. In their assessment, respondents may have been biased towards the most recent drought experienced (compare the SOI Index in Fig. 6, sub-project B).

Regarding the perceived length and severity of drought periods, differences were observed between the geographically distinct sub-districts of Sigi Biromaru (the low-lying Palu valley), Kulawi (600-1000 m a.s.l.), and the Palolo valley (550-650 m a.s.l., Table 1). On average, the most severe drought had caused the yields of both irrigated rice and cocoa to decline to about 70% of their usual level. The yield decline in Sigi Biromaru was more pronounced than in Palolo and Kulawi (Table 2). Within Sigi Biromaru, a difference in rice yield decline was observed between the three research villages. This difference may be attributed to the quality of irrigation, as reflected by the drop in water availability during the drought as compared to a 'normal' season (Table 3).

Figure 9 visualizes the differences in perceived rainfall and related availability of irrigation water in these villages, based on the RRA discussions. In Pandere, water is abundant all year round. It is the first village to receive water within a technical irrigation system, which is serviced by Gumbasa River with a minor variance in water flow as shown by sub-project B (Fig. 7).

Maranata is connected to the same irrigation scheme, but is located further downstream. Thus, a seasonal decline in water availability can be observed. Sidondo II receives water from small streams with a higher seasonal variance in water supply, comparable to the situation depicted in Fig. 8 of sub-project B. Across the whole research area, 83% of HHs have been negatively affected by at least one drought. In order to cope with decreased agricultural income during that period, 63% of these HHs reduced expenditures, 46% earned income from sources that are usually not utilized, and 21% took a loan (multiple responses possible). Figure 10 provides a more detailed overview of expenditure reductions in different categories. The dominant additional income sources during the drought were temporary employment (72%) and the sale of rattan (28%, multiple responses possible).

Table 2. Yield decline of irr. rice and cocoa due to most severe drought experienced, differentiated by sub-district

Sub-district	N Rice	Rice yield in most severe drought season (% of 'normal' yield)*	N Cocoa	Cocoa yield in most severe drought year (% of 'normal' yield)**
Sigi Biromaru	67	60.9 [a]	18	44.2 [a]
Kulawi	60	76.1 [b]	32	71.7 [b]
Palolo	23	77.6 [b]	36	75.8 [b]
Total	150	69.5	86	67.8

*(**) Homogeneous subsets (a, b) based on Student Newman Keuls Test, $P < 0.05$ ($P < 0.01$)
Source: Own data

Table 3. Yield decline of irrigated rice due to most severe drought experienced in sub-district Sigi Biromaru, differentiated by research village

Village	N	Rice yield in most severe drought season (% of 'normal' yield)*	Drop in water availability score between 'normal' and drought season (Water availability score: 1 = very poor, …, 5 = ideal)**
Sidondo II	6	52.8 [a]	1.15 [a]
Maranata	41	54.1 [a]	1.48 [a]
Pandere	20	77.3 [b]	0.09 [b]
Total	67	60.9	1.03

*(**) Homogeneous subsets (a, b) based on Student Newman Keuls Test, $P < 0.10$ ($P < 0.01$)
Source: Own data

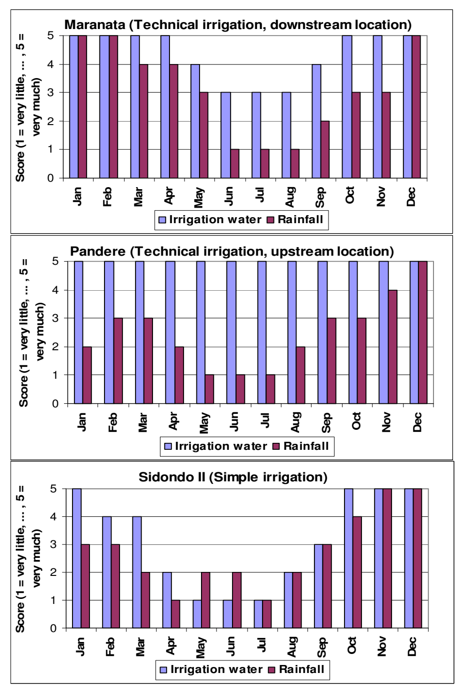

Fig. 9 Perceived rainfall distribution and related availability of irrigation water during a 'normal' year in three villages in Sigi Biromaru sub-district.
Source: Own data

5.4. Planned activities of Sub-Project C

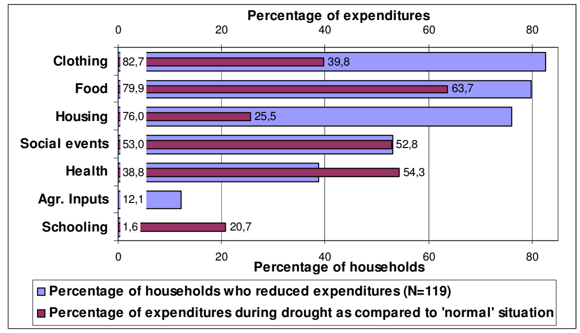

Fig. 10 Reduction of household expenditures as a strategy to cope with the effect of drought
Source: Own data

As specified above, production functions will be estimated for irrigated rice and cocoa. Using consumption and expenditure related indicators, an index will be developed which measures the extent to which a household is affected by drought, and regression analysis will be applied to identify its determinants. In all regression models, stochastic simulation will be incorporated to produce results which are more realistic than those of deterministic models. In the last two years of the five-year project period, the models produced by all sub-projects will feed into a joint linear programming model, which will allow us to analyze scenarios for typical farm households that will be defined on the basis of the household survey. Our simulations will include different projections of water availability and policy instruments that can be implemented to mitigate the impact of climate variability.

6 Conclusions

The results obtained by the three sub-projects during the first two years corroborate the premise that the local and regional manifestation of El Niño in the IMPENSO research area has far-reaching implications for water availability and for the livelihoods of the local communities.

As the results of **Sub-project A** demonstrate, the atmosphere circulation shows a typical situation for the El Niño events in the research area. ENSO has a clear impact on the precipitation variability during the dry season (June – October in Kulawi), rather than during the rainy season. On a monthly basis, the model results and field measurements of precipitation data correspond very well to each other in the plain region of South Sulawesi, but not yet in the structured mountainous area of Central Sulawesi. With the REMO model, it is possible to reproduce the El Niño events with lower precipitation rates and the La Nina events with higher precipitation rates for larger areas in Indonesia. These conclusions support the plan of sub-project A that the regional model REMO will have to be nested with an atmospheric model of small size (GESIMA) to improve the agreement of measured data and model results in mountainous areas. It also became evident that the number of field measurements of precipitation rates performed by the Indonesian Meteorological and Geophysical Agency are not sufficient for atmospheric model validation, so that field measurements of other agencies will have to be recovered and integrated into our measurement net.

In **Sub-project B**, the analysis of a six year time series of discharge data of one sub-catchment of the Palu River watershed has shown that rainfall anomalies caused by ENSO events have a significant effect on the streamflow, even in a small sub-basin of the study area. Analysis of observed discharge data for different sub-basins indicate that current land use with respect to the sub-basin characteristics has an impact on the hydrological behavior of the basin. Thus, the potency of the impact of ENSO events on the hydrology is expected to be connected to the current land cover of the watershed area. This led to the conclusion that we have to integrate the impact of current rapid land use changes on the water resources into water resource scenarios of the catchment area.

The results of **Sub-project C** also confirmed that, despite its location close to the equator, unusually extensive drought periods do occur in the research area, causing a substantial decrease in the yields of the most important crops, irrigated rice and cocoa. As the data collected by sub-project C show, the severity of droughts differs within the mountainous region, and in the case of rice, the type of irrigation facilities also influences the extent of yield decline. The dominant strategies of the local communities to cope with the impact of drought are the reduction of expenditures for clothing, food, and housing, and the utilization of additional income sources, especially temporary wage labor and the sale of rattan. The role of credit is also substantial.

In the next project phase, the data and models of the three sub-projects will be linked for the simulation of joint scenarios that will be used to evaluate different policy options to cope with ENSO. The basis for this integrated modeling has been provided by the close **collaboration** of the three sub-projects during the current phase, which included joint planning, coordinated data collection in the field, and joint stakeholder workshops (see Section 8).

7 Cooperation Within DEKLIM and With Other Programs

As the above description of activities shows, there has been an intensive cooperation with the Indonesian-German research project STORMA ("Stability of Rainforest Margins", DFG-Sonderforschungsbereich 552), which is operating in the same region. The possibility to jointly collect and use data on climatology, hydrology and socio-economics has been a distinctive benefit for both IMPENSO and STORMA. The German Research Foundation DFG has recently approved the second phase of STORMA, so that the fruitful cooperation will continue. We expect particular benefits from our close collaboration with the recently established integrated modeling project of STORMA, which is operated by the Center for Environmental Systems Research of Kassel University (Prof. Dr. J. Alcamo, Dr. J. Priess). In Indonesia, a close collaboration has been established both with the regional University in Palu (TADULAKO) and at the national level with the Institut Pertanian Bogor (IPB), the leading Agricultural Research Institute in Indonesia.

The coordination activities within DEKLIM, especially the Kick-off Workshop and the DEKLIM C Coordination Workshop held in Bremen in November 2002, provided good opportunities for establishing a cooperation with the other three DEKLIM projects dealing with climate impact research. Benefits were derived from the discussion of methodological approaches to similar problems, especially the operationalisation of the concept of vulnerability, which is a common concern of all four DEKLIM C projects. The collaboration within DEKLIM C will also allow us to compare results and discuss policy options with the Project on "Security Diagrams" (Center for Environmental Systems Research, Kassel), which is working in developing countries, too. IMPENSO will also contribute to and benefit from the development of tools for integrating data and models from the natural and the social sciences, which is supported as a crosscutting task by the speakers of DEKLIM C and a researcher especially employed for this task.

The use of the REMO model involved a close collaboration with the Max Planck Institute of Meteorology in Hamburg. We also established a cooperation with two projects in the BMBF program on Global Change in the Hydrological Cycle (GLOWA), the GLOWA-Elbe and the GLOWA-Volta project, because they also deal with climate impact on water resources and socio-economic conditions, using comparable methodological approaches, thus providing good opportunities for exchanging experience and knowledge. Together with the Center for Development Research (ZEF), which is in charge of GLOWA-VOLTA, and with IFPRI (International Food Policy Research Institute), we submitted a concept note (accepted in June 03) to the international Water Challenge Program of CGIAR (Consultative Group on International Agricultural Research) for a project focusing on the use of integrated models in multi-stakeholder watershed governance systems, a topic that is of particular importance for IMPENSO, thus offering good opportunities for cooperation at the international level. We also applied for the association of IMPENSO with the Land Use and Land Cover Change Program (LUCC) of the International Human Dimensions Program on Global Environmental Change (IHDP) and participated in the IHDP Berlin Conference on the Human Dimensions of Global Environmental Change.

8 Policy Relevance and Application

Our findings concerning the importance of ENSO in the research area underline the policy relevance of IMPENSO's objective to study the impact of climate variability at the regional and local scale. The considerable spatial variation of the impact of ENSO in the research region implies that there is a need to improve the forecasting possibilities for ENSO at a smaller scale than currently practiced. Thus, developing the forecasting methodology at this scale, as pursued in Sub-project A, is an indispensable contribution to the development of better coping strategies. Likewise, hydrological modeling at the meso-scale, using climatological model results as input data, as pursued in Sub-project B, is a very policy-relevant contribution as it creates the essential link between climate variability and water availability, which ultimately affects crop yields and rural livelihoods. Hydrological modeling also demonstrates the effects of deforestation on water availability, which is policy-relevant in view of the rapid deforestation observed in the research area. The participatory appraisal conducted by Sub-project C in collaboration with Sub-projects A and B were important to elicit the views, perceptions, problems, and the already existing coping strategies of the local communities concerning the climate variability caused by ENSO. Current coping strategies such as reducing food expenditure or increasing rattan collection in primary forests are problematic from a food security perspective and from an environmental policy perspective, which underlines the need to develop alternative coping strategies. The analysis of the vulnerability of different groups of households conducted by Sub-project C is essential for the targeting of policy measures to those community members that are most affected by ENSO. Our research indicates that policy options aimed to improve the coping capacity for ENSO include technical and institutional solutions, such as improved water resources management, adaptation of cropping techniques that farmers can apply when improved ENSO forecasts are available, improved access to credit for vulnerable households, and innovative insurance instruments.

To assure that the research results will be user-oriented and practically applicable, IMPENSO has placed a high emphasis on working together with Indonesian institutions since the start of the project. The research associate of Sub-project A is a member of the Indonesian Meteorological Service, which has ensured a close collaboration with this agency. Our Indonesian counterparts plan to apply, throughout the country, the methodology developed in IMPENSO for the improvement of meso-scale ENSO forecasting. Within IMPENSO, the transfer pathway for atmospheric information from the Indonesian Meteorological Service to the local farmers will be analyzed, assessed and evaluated in order to improve the communication of the available atmospheric information to local farmers. In this context, the collaboration with the Agricultural Extension Service and the government agencies in charge of irrigation is particularly important. IMPENSO has established a close collaboration with these state agencies and also with the non-governmental organizations (NGOs) working in the research region, which will integrate IMPENSO results into their project activities. To facilitate the cooperation with the Indonesian partner institutions, two workshops, which served as milestones in the research process, have been conducted in Palu, one in the beginning of the field research in Indonesia to ensure far-reaching stakeholder participation, and one after a period of one year to communicate and discuss the first. Feed-back was also provided to the local communities. Thus, a sound basis has been established for the further tasks of IMPENSO, especially the simulation of policy scenarios for the identification of policy options that will improve the capacity of local communities to cope with ENSO.

Annex: Map of the Research Region