

Impact of global climate change and desertification on the environment and society in Southern Centre of Vietnam

(Geographic) study area (country/region): Binh Thuan province, Vietnam

Context and objectives

1. Context

Vietnam is one of the countries in South-East Asia that is severely affected by climate change. The country has about 21 million hectares of agricultural and forest land, and the surface affected by drought is approximately 9.34 million hectares (approx. 45%) of the total agricultural land. Of these, about 7.8 million hectares (or approx. 30% of the total country's agricultural and forest land) are severely degraded. Desertification and drought mainly occurs in the Southern part of Central Vietnam, including the provinces of Binh Thuan, Ninh Thuan, and Khanh Hoa, which cover about 300,000 hectares.

Binh Thuan is the most seriously affected province by prolonged drought during recent years. The areas near the coast of this province have an arid and hot climate with an annual rainfall of 500-700 mm in the worst affected areas. The lack of water for the households and agricultural production during the 6-month dry season offers a serious threat to rural life. Additionally, the communities face difficulties due to prolonged droughts that affect all traditional uses of land and water resources such as water storage, farming activities, and hillside cultivation. In the Binh Thuan province unsustainable farming practices and deforestation are reported as the main reasons for desertification and land degradation.

International, regional and Vietnamese studies show that scientific, technological, and policy responses are needed to combat climate change and desertification. In Central-Southern Vietnam, projects have been implemented to study climate change and its effects. In these studies, the main focus was on sea level rise, floods and storms. Systematic and integrated research on drought and desertification and the impacts on the biophysical and social environment has not been addressed. This project aimed to address this gap such that policy responses can be adequate.

2. Objectives

The *main* objective of the project is to enhance the understanding of the impacts of drought using a multi-factorial approach. The results will contribute to policy making and to mitigate adverse impacts of the global climate change and desertification on the human welfare in Southern Central Vietnam. The focus will be on an adaptation strategy to increase the resilience of the local communities and a more rational use of the agricultural resources in environmental sensitive areas.

The *specific* objectives are to:

- describe and analyse primary information for indicators and aspects related to desertification (WP1);
- assess the current status of desertification and drought stress based on the analysis of meteorological data, land use changes and soil characteristics. To forecast desertification related climate parameters (WP2);
- study the impacts of drought stress on selected socio-economic aspects: water availability and accessibility, shifts in agricultural crops, income, expenses, poverty and migration (WP3); and,
- provide an integrated risk assessment as a basis for mitigation and adaptation options (WP4).

Methodology

1/ WP1: Data collection

- Field surveys and interviews of 208 households;
- Geodatabase development (topography, geomorphology, hydrology, climate, vegetation, soil, land use, drought, natural resources, economy);
- Multiple year Landsat and SPOT4-HR images and SPOT-VGT 10-daily synthesis NDVI data;
- Hydro-meteorological data for the period 1976-2009 in two stations in Binh Thuan and 4 stations in the vicinity;
- Vietnamese/IPCC scenarios to forecast effects of climate change;

2/ WP2: Bio-physical impacts

- Statistical and spatio-temporal analysis of available meteorological data;
- Climate modelling: CCCMA-T47, INGV, IPSL.
- Agricultural meteorological analysis: ET0, Aquacrop, Rainbow, Budget.
- Processing of GIS and remote sensing images for land use changes
- Risk, sensitivity, vulnerability assessment using spatial analysis: aridity index, biomass potential, yield.
- Quantitative assessment using bio-physical modelling

3/ WP3: Socio-economic impacts

- Statistical analysis of available data on agricultural production, income, poverty, and migration.
- Survey using household, questionnaires and semi-structured reviews

- Relating statistical data to thematic maps.
- Delphi method to analyse causes and effects of desertification.
- Leopold matrix to establish cause-effect relationships of desertification.

4/ WP4: Mitigation and adaptation options

- Analytic Hierarchy Process (AHP) to weight and prioritize causes and effects of drought;
- Risk assessment of the bio-physical and social-economic aspects of drought
- SWOT (Strengths, Weaknesses, Opportunities, Threats) to analyse the responses to drought;
- The important elements for drought policies emerging from this research were summarized in a context of terms of reference (ToR) for a strategic environmental assessment (SEA).

Scientific Results

1/ WP1: Data collection

- The two most North – Eastern districts (Bac Binh and Tuy Phong) of the province are most vulnerable to drought;
- A database and an atlas with 24 thematic maps (1/100.000 scale for the province and 1/50.000 scale for the districts). Such a data base is a new instrument supporting policy in Binh Thuan. More data are available on the bio-physical than on the socio-economic aspects of Binh Thuan;
- Meteorological data are available for a period of 30 years (1978-2009). This should be sufficient to reflect climatic changes, that according to Vietnamese researches, become manifest from 1990 – 1995 onwards. Compared to the international literature, this period is short.
- Climate change scenarios for Binh Thuan province included the variation in rainfall, temperature, sea level rise, and hydrology for each decade from 2020 to 2100. Application of the IPCC scenario's to Binh Thuan shows that the province will face less rain and more extreme climate events during the decades to come.
- The impacts of climate change and desertification were analysed for water, soil, and ecological/biological factors and socio-economic activities. Coastal groundwater resources are threatened by salinisation. Four types of soil degradation are described: sand dune formation, salinisation, clay dust formation, water erosion and rock outcrops. Four ecosystems have been described: the coastal area, the sand dune ridge, the agricultural belt and the forest. Concerning ecosystems the study paid special attention to forest biodiversity.
- Technical and managerial options to cope with drought are proposed. Among the technical ones are more efficient irrigation systems and rational water use.
- Among the managerial options, specific attention is paid to the selection of crops in association with the soil type and the varying onset and duration of the rainy season.

A major conclusion is that the two most North-Eastern districts (Bac Binh and Thuy Phong) of the Binh Thuan province are most vulnerable to drought. The main limitations are the relatively short time series for meteorological data (30 years) and crop production data (20 years) made available.

2/ WP2: Bio-physical impacts

2.1. Assessing changes based on observations (1970 – 1999) and projections (2046-2065; 2081-2100):

- Binh Thuan experiences a rainfall of an average 1130 – 1340 mm per year, which might drop during the next decades. 90% of this rain is provided during the 110-135 days the wet season lasts. The climate in the province is further characterised by high evapotranspiration (1350 mm) and abundant sunshine (2500 – 2800 hours per year). Of notice is the variable onset of the wet season.
- An increase of the average temperature of 1.6 °C (by 2046-2065) to 2.5° C (by 2081-2100) is projected. Extreme temperatures and rainfall events need to be taken into account. In combination with the declining rainfall, this will intensify drought. An increase in the duration of the dry season is projected for the period 2046-2065, without dramatic changes in the total amount of rain.
- The general picture that emerges from this analysis is that Binh Thuan is among the driest areas in Vietnam. Climate models allow projecting an increase in temperature, less rain, a longer dry period and more extreme weather events.

2.2 Land cover change (LUC) analysis (1990-2002):

- Forest covers half of the province (47% in 2010). The forest cover declines by 3% during the period 2005-2010.
- The agricultural land increased by 10% during the 2005-2010 period. Almost 20% of the land (19%) is used to grow perennial crops.
- Settlements occupy increasingly larger areas and occupy 3.5% of the land in 2010.
- Other land covers include water and aquaculture (1%) and marginal land (4%).

2.3 Drought Characterisation:

- The data contributes to a classification of two climatic regimes in Binh Thuan: wet in the Western part of the province and semi-arid in the East. The areas most sensitive to drought are located in the North-Eastern part of the province and coincide with the Bac Binh and Tuy Phong Districts.
- Most of the climatic variation concerns the onset and the duration of the rainy season. However, in particular the start of the rainy season is expected to delay further during the decades to come.
- Increases in agricultural biomass and yields were documented both on ferralsols and arenosols during the past 30 years (1980 – 2009). However, clay containing soils are more productive than sandy soils.
- Areas in the neighbourhood of water reservoirs are particularly vulnerable to erosion. On these soils, erosion can be mitigated by afforestation.

The research pointed to the need of longer term data to study the effects of a changing climate on desertification in the Binh Thuan Province.

3/ WP3: Socio-economic impacts

This WP deepens the socio-economic effects of drought in Binh Thuan. The results are based on the analysis of official statistical data, family and authorities questionnaires, and spatial analysis of the geo-database. Cause-effect relationships are assessed using a Leopold matrix that was established using a Delphi approach and involving 23 Vietnamese experts.

- 27 cause and 22 effect indicators were identified that according to the panel of experts, were of particular importance to drought in Binh Thuan. Land use planning, surface water, and dry periods were the most important drought related causes of socio-economic effects in the province. They mainly impacted agricultural production, water supply both for agriculture and for households, and rice production. Water availability for agriculture mainly depends on irrigation that is collected by dams; 10% of the agricultural land is currently irrigated;
- Over 50% of the households depend on tap water for drinking and personal hygiene. Most vulnerable to drought are the families that use well water (over 40%) and rain water (less than 5%). Developments in agriculture are driven by the availability of irrigation water.
- Local communities adapt to drier conditions by selecting new crops: areas and production of drought stress resistant crops such as dragon fruit increase. New crops, that demand less water, such as jatropha and sterculia, are introduced. The area where rice is grown depends on the availability of irrigation water. It decreases when no water is available; it increases as soon as new dams provide water all over the year.
- The families report an average yearly income of 110.328.078 VND (4,000€). Significant variations exist according to location and source of income. Income levels are higher in the coastal area (aquaculture, tourism) and among cattle breeders. There are no indications that income is negatively affected by increasing drought.
- Households in the surveyed area report to spend on average 52.865.263 VND a year. Most money goes to basic food and investments in properties. Expenditures are characterized by significant variations according to communes and type of expenditure. No indications were collected of influence of drought on expenditure.
- Overall 12% of the households in the study area are classified as poor. By commune, the figure varies between 31 and 0 %. There is no indication that poverty is associated with drought.
- The population in the study area shows a modest growth. Moreover there is a minor rural outmigration that is below the Vietnamese average.

These results are discussed in a context of resilience, uncertainties and future directions of research. In conclusion, the farmers manage to adapt to the slowly progressing drought stress in the province by investing in irrigation and by selecting their crops in line with the changing environmental conditions. Alternative options to traditional farming including new crops, aquaculture and tourism, have an important role in the transition processes. The relatively high income in the area allows investments, increases resilience and seems to counteract out-migration.

4/ WP4: Mitigation and adaptation options

The results of the previous WPs were complemented with a risk assessment and a ranking (AHP) of causes and effects of drought in Binh Thuan, best practices to deal with drought, a cost-benefit analysis of selected policy option, and a SWOT analysis of the local situation.

- The results of the AHP methods show that water supply, immigrant-resettlement and forest conversion were considered as the most important causes of drought. Water resources for households, agriculture, and aquaculture, agricultural practices (especially for rice cultivation), and socio-economic activities were considered as the most important effects.
- Current adaptation policy options include the installation of irrigation dams. Increased irrigation leads to increased agricultural production and enables the population to bridge the dry season gap. An active agricultural policy to cultivate less water demanding crops is part of the adaptation measures.
- A combined SWOT and risk assessment analysis was carried out to uncover strengths, weaknesses, opportunities and threats of strategic adaptation policies to desertification and climate change for the major sectors: agriculture, forestry, aquaculture and fisheries, water & natural resources and supply, industry, land use planning.
- This allowed to advocate an integrated and comprehensive drought policy (including strategic management of water resources, proper land use, protection of in particular the forests and dunes, and maintenance of the current income trends), its instruments (ecosystem conservation and water management plans, increasing the resilience of the agriculture, monitoring, and specific interventions as insurance systems), and the main stakeholders/target groups (farmers, poor, administration)
- An outline for SEA provides a basic framework to assess future development projects on their environmental and social merits. The SEA specifically includes the results that emerged from this study.
- An analysis of three scenario's (low-mid-high) shows that for the Binh Thuan Province between 5.42 and 10.8% of the population (mid: 60,964.09 people) will be affected, and between 2.55 and 5.00% of the land (mid: 19,063.52 ha) will be damaged mainly as a result of sea level rise. This will result in an estimated 4.2 to 10.0% decrease of the GDP (mid: 963,953.02 million or €34.2 million).

The combination of the bio-physical-socio-economic data with the results of the analyses in WP4 is new for Vietnam and Binh Thuan. This type of policy support is highly appreciated.

Conclusions

- The climate in Binh Thuan is characterized by an average annual rainfall of 1130-1340 mm and a high annual evapotranspiration of 1350 mm, which points to a dry climate. Drought in Binh Thuan is characterized by a significant variation in the onset of the rainy season. The IPCC climate models project an average temperature increase of 1.6°C by the middle of this century leading to a progressing drought.
- Observations show that the total amount of rainfall does not change in Binh Thuan. However, the length of the dry season varies considerably. This affects the flow of water in the rivers and the replenishing of groundwater layers.
- The hydrological regime also contributes to soil degradation. Areas with a high rainfall intensity (e.g. in the Bao Lac and Xyan Loc communes) are prone to erosion. In the coastal area the sand dunes are subject to movements, notably in the Bac Binh and Tuy Phong districts. The clay soils, bordering the ancient river banks, dry out, become arid and hard owing to laterite formation. Four types of soil degradation are discerned: sand dune formation in the Central-Eastern part, salinisation of soils in the areas bordering the sand dunes, wind and water erosion on clay soils, laterite formation, and erosion with rock outcropping in the mountains.
- The human activities in Binh Thuan are determined by the ecosystems: a sandy coastal area in the East (13% of the land) a central agricultural belt (20%) and mountains in the West (47 %).
- The changing bio-physical characteristics affect agriculture. Farmers move to drought resistant crops such as cassava and cashew, while water demanding crops as paddy rice, are increasing in the irrigated parts of the province. Dragon fruit is a lucrative opportunity crop in the province.
- There are no indications of shortage of surface and groundwater availability for the households, although the drinking water reserves are at risk of depletion (surface water) and salinisation (coastal groundwater).
- The main policy response to drought in Binh Tuan is building dams to collect water for household use and irrigation. Currently in Bac Binh and in Tuy Phong 17,800 ha of the land is irrigated and more dams are planned. In the short term, irrigation increases the income of the farmers which contributes to their resilience, keeps poverty to low levels and prevents out-migration of young adults. On the other hand, the dam policy contributes to coastal erosion and changes the river banks.
- Binh Thuan is in need of a more comprehensive drought policy that takes into account the negative effects of dam construction, the risks related to drinking water availability, waste water management and the protection of the ecosystems. A main target should be rational water use. This policy should be driven by managerial (planning for specific issues, SEA), technical (advanced irrigation), economic (water fees), monitoring and training instruments. It should address the main stakeholders (farmers, households, tourism) in the province. This integrated policy should be evidence based and use the results of risk analysis, priorities in causes and effects of drought, cost benefit approaches and best available technologies.
- Drought policy in Binh Thuan is in need of research support. Most of the research is analytical and descriptive. More attention should go to the bio-physical and socio-economic mechanisms that drive drought induced changes. Moreover applied research e.g. on how to implement rational water use and integrated water management in the province should be undertaken. A proposal along these lines should be submitted in line with the BTC activities and complementary funding by Belspo (Bilateral agreement). In Vietnam, the same project should be submitted to the Binh Thuan People's Committee and Ministry of Planning and Investment.

Products and services

Journal papers:

- Hountondji Y, de Longueville F., Ozer P. (2012). Land cover dynamics (1990-2002) in Binh Thuan province, Southern Central Vietnam. *International Journal of Asian Social Science*, 2(3): 336-349. <http://hdl.handle.net/2268/116012>
- Le Trinh H., A. Gobin, L. Hens. Selection of sustainability indicators of cause and effect for identification of the impacts of desertification for Binh Thuan province, Vietnam. Submitted to the journal of Ecological Indicators <http://www.journals.elsevier.com/ecological-indicators/>
- Le Trinh H., A. Gobin, L. Hens. Uncovering causes and effects of desertification using a Leopold matrix in Binh Thuan Province, Vietnam. Submitted to Human Ecology <http://www.hunter.cuny.edu/humaneco/human-ecology-an-interdisciplinary-journal>
- Gobin, A., Pham Ha, L., Le Trinh H., Le Thi Thu, H., L. Hens, Pham Quang, V. Mitigation and adaptation options to drought and desertification in the binh thuan province of vietnam. In preparation – Environmental Science and Policy or Land Use Policy
- Le Trinh H., A. Gobin, L. Hens. Application of analytic hierarchy process to propose and priority solutions – a case study in the province of Binh Thuan, Vietnam. Submitted to the Journal of Environmental Management <http://www.journals.elsevier.com/journal-of-environmental-management/>
- Le Trinh H., A. Gobin, L. Hens. Risk assessment for desertification and climate change – a case study in Binh Thuan province, Vietnam. Submitted to the Journal of Human and Ecological Risk Assessment <http://www.tandf.co.uk/journals/titles/10807039.asp>
- Gobin, A., Nguyen Trong, H., Pham Quang, V., Pham Thi Thanh H. Heavy rainfall distribution during ENSO cycles and the impact on flooding and paddy rice cultivation in Vietnam. Submitted to Natural Hazards and Earth System Sciences. <http://www.natural-hazards-and-earth-system-sciences.net/>
- Ozer P. (in preparation). Disparition du village de pêcheurs de Phan Thiet (Vietnam): reflexions sur les representations des risques climatiques en milieu côtier, GEO-ECO-TROP.

International conference proceedings:

- Doutreloup, S, Erpicum, M, Fettweis, X, & Ozer, P. (2011). Analysis of the past (1970-1999) and future (2046-2065 and 2081-2100) evolutions of precipitation and temperature, in the Province of Binh Thuan, South East Vietnam,

based on IPCC models. *Proceedings of the 1st International Conference on Energy, Environment and Climate Change, August 26-27 2011, Ho Chi Minh City, Vietnam*. Available at <http://hdl.handle.net/2268/96759>

Hountondji, Y., & Ozer, P. (2011). Land use and land cover change analysis 1990-2002 in Binh Thuan Province, south central Vietnam. *Proceedings of the 1st International Conference on Energy, Environment and Climate Change, August 26-27 2011, Ho Chi Minh City, Vietnam*. Available at <http://hdl.handle.net/2268/97731>

Ozer P. (2012). Non, le village de pêcheurs de Phan Thiet (Vietnam) n'a pas été victime du changement climatique, Selected for presentation at the *Colloque international Géomatique et gestion des risques naturels, 6-8 mars 2012, Oujda, Maroc*.

Gobin, A., Le Trinh H., Pham Ha L., L. Hens. Land use and desertification in the Binh Thuan Province of South-eastern Vietnam: mitigation and adaptation options now and under climate change. Selected for presentation at the European Geophysical Union General Assembly 2012, at Vienna.

Reports, databases and other services

Summary reports and power point presentations for each of the four work packages.
Geo-atlas of Binh Thuan Province with 24 thematic maps.
Relational data base on statistical data (agriculture, forestry, population, economy).
Strategic Environmental Assessment concept note.

Project Execution

Period: 2009 – 2012

Coordination in Vietnam

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Withdrawn from the project in November 2011

Discipline

- Human ecology
- Environment
- Ecology
- Sustainable development
- Climate change, drought
- Desertification

Ideas for future research

Further topics for research include:

- Natural resources management now and under scenarios of climate and land use change
- Climate impacts and extreme weather events in relation to agricultural production and food security
- Carbon management in soil, agriculture & forestry linked to the bio-energy debate
- Meteorological risks as drivers for efficient natural resources management