

# CLIMATE RISK MANAGEMENT FOR WATER AND AGRICULTURE IN THE DOMINICAN REPUBLIC: FOCUS ON THE YAQUE DEL SUR BASIN

Prepared by the International Institute for Sustainable Development (IISD)

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CRISIS PREVENTION AND RECOVERY





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## FOREWORD

Climate change has the potential to exacerbate conflict, cause humanitarian crises, displace people, destroy livelihoods and set-back development and the fight against poverty for millions of people across the globe.

For example it is estimated that over 20 million people in the Mekong Delta and 20 million in Bangladesh could be forced to move as their homes are affected by salt water incursion from rising sea levels. Entire populations of some low lying island states, such as Nauru or the Maldives may have to be relocated. In countries like Honduras, where more than half the population relies on agriculture, climate induced risks, such as Hurricane Mitch in 1998, which caused over US\$ 2 billion in agricultural losses, will continue to pose a staggering potential for damage. Similarly, climate risk assessments in Nicaragua show that changes in rainfall patterns, floods and drought could put human health at risk by increasing the prevalence of respiratory and water borne diseases and malnutrition.

Long-term incremental changes will mean that people everywhere must learn to adapt to weather or rainfall patterns changing or shifts in ecosystems that humans depend upon for food. Perhaps more worrying however, is that climate variability and change will also bring unpredictable weather patterns that will in-turn result in more extreme weather events. Heat waves, droughts, floods, and violent storms could be much more common in the decades to come. Climate change is “loading the dice” and making extreme weather events more likely. These disasters will undermine the sustainability of development and render some practices, such as certain types of agriculture, unsustainable; some places uninhabitable; and some lives unliveable.

As climate change creates new risks, better analysis is needed to understand a new level of uncertainty. In order to plan for disasters, we need to understand how climate change will impact on economies, livelihoods and development. We need to understand how likely changes in temperature, precipitation, as well as the frequency and magnitude of future extreme weather will affect any sector, including agriculture, water-use, human and animal health and the biodiversity of wetlands.

This report is a product of the Climate Risk Management – Technical Assistance Support Project, which is supported by UNDP’s Bureau for Crisis Prevention and Recovery and Bureau for Development Policy. This is one in a series of reports that examines high-risk countries and focusses on a specific socio-economic sector in each country. The series illustrates how people in different communities and across a range of socio-economic sectors may have to make adaptations to the way they generate income and cultivate livelihoods in the face of a changing climate. These reports present an evidence base for understanding how climatic risks are likely to unfold. They will help governments, development agencies and even the communities themselves to identify underlying risks, including inappropriately designed policies and plans and crucial capacity gaps.

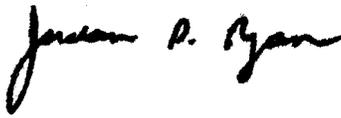
This series is part of a growing body of climate change adaptation resources being developed by UNDP. The Climate Risk Management – Technical Assistance Support Project has formulated a range of climate risk management assessments and strategies that bring together disaster risk reduction and climate change adaptation practices. The project is designing a common framework to assist countries in developing the necessary capacity to manage climate-induced risks to respond to this emerging threat. The climate risk assessments discussed in this report and others in the series will feed into a set of country-level projects and regional initiatives that will inform the practice of climate risk management for decades to come.



Addressing climate change is one of UNDP's strategic priorities. There is a strong demand for more information. People at all levels, including small communities want to understand the potential impact of climate change and learn how they can develop strategies to reduce their own vulnerability. UNDP is addressing this demand and enabling communities and nations to devise informed risk management solutions. UNDP recognises that climate change is a crucial challenge to sustainable development and the goal of building resilient nations.

As the full effect of climate change becomes apparent, it is assessments such as these that will become the lynchpin of national responses and adaptation strategies for many years to come. Like the threat from many disasters, there is still time to prepare for the worst impacts of climate change in developing countries if we expand our understanding now.

This knowledge must be combined with real preparedness and action at all levels. Only then will we be able to stave off the worst impacts of climate change in the most vulnerable and high risk countries of our world.



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The general methodology and analytical framework of the CRM TASP was conceptualized by Maxx Dilley, disaster partnerships advisor, and Alain Lambert, senior policy advisor, with key inputs from Kamal Kishore, programme advisor, Disaster Risk Reduction and Recovery Team, BCPR, in consultation with Bo Lim, senior climate change advisor, Environment and Energy Group, BDP. Within BCPR, the project implementation process has been supervised by Alain Lambert, Rajeev Issar and Ioana Creitaru, who provided regular inputs to ensure in-depth climate risk assessments and identification of tangible risk reduction and adaptation options. From BDP, Mihoko Kumamoto and Jennifer Baumwoll provided their input, comments and oversight to refine the assessment and recommendations. The overall project implementation has benefitted immensely from the strategic guidance provided by Jo Scheuer, coordinator, Disaster Risk Reduction and Recovery Team, BCPR, and Veerle Vandeweerd, director, Environment and Energy Group, BDP.

The climate risk assessments under the CRM TASP have been undertaken with the funding support of the Government of Sweden.

Building upon the general framework of the CRM TASP and tailoring the process to country-level analysis, IISD developed a more detailed methodological framework for assessing climate risks and identifying climate risk management options in seven countries, including the Dominican Republic. Within IISD, Anne Hammill supervised the overall project implementation. Marius Keller supervised all in-country activities in the Dominican Republic and is the lead author of the present report.

For their valuable contributions to the project, the project team would like to thank co-author Alicia Natalia Zamudio-Trigo; consultants Arnulfo Gonzalez Meza, Alejandro Herrera-Moreno and Juan Carlos Orrego Ocampo; Raúl Pérez, Fidel Perez, Juan Chalas, Juanito Montilla and Luis Bello of the National Institute for Hydrological Resources (INDRHI); Elpidio Tineo and Eduardo Julia from Fundación Sur Futuro; and Francisco Flóres-López of the Stockholm Environment Institute. The project team would also like to thank Maria Eugenia Morales, Carol Franco Billini and Ana Maria Pérez of UNDP Dominican Republic for assisting with the coordination of the project and providing feedback on this report and other project outputs, and for useful comments and feedback on various drafts of this report; and all the participants of the final review workshop.

## LIST OF ABBREVIATIONS AND ACRONYMS

CEPREDENAC	Coordination Center for the Prevention of Natural Disasters in Central America
CNCCMDL	Council for Climate Change and the Clean Development Mechanism
CRiSTAL	Community-Based Risk-Screening Tool
CRM TASP	Climate Risk Management Technical Assistance Support Project
DIPECHO	European Commission Humanitarian Aid Department's Disaster Preparedness Programme
DSSAT	Decision Support System for Agrotechnology Transfer
FAO	Food and Agriculture Organization of the United Nations
HDI	Human Development Index
IFAD	International Fund for Agricultural Development
IISD	International Institute for Sustainable Development
INDRHI	National Institute for Hydrological Resources
IPCC	Intergovernmental Panel on Climate Change
JAD	Dominican Agribusiness Board (Junta Agroempresarial Dominicana)
MDG	Millennium Development Goal
NGO	non-governmental organization
PSD	participatory scenario development
SEMARENA	State Secretariat for Environment and Natural Resources
SICA	Central American Integration system
SNPMRD	National System for Disaster Prevention, Mitigation and Response
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
WEAP	Water Evaluation and Planning

## EXECUTIVE SUMMARY

This report presents the main results of a climate risk and risk management capacity assessment of the agricultural and water sectors in the Yaque del Sur watershed of the Dominican Republic, conducted as part of the Climate Risk Management Technical Assistance Support Project (CRM TASP) of the United Nations Development Programme (UNDP). The combination of different scientific and participatory research streams, including literature reviews, community consultations, and crop and water management modelling, as well as policy and capacity assessments, provides a basis for identifying climate risks in the selected watershed and prioritizing measures to manage them. Several national experts, key governmental and non-governmental agencies, and international water, agriculture and climate specialists were involved in the research.

The Dominican Republic is an upper-middle-income country, yet good average income levels hide development challenges such as high inequality, insufficient education and health, and gender inequality. The 'National Development Strategy' aims to strengthen good governance, reduce poverty and inequality, and pursue economic integration and environmental sustainability. The agricultural sector provides employment to a large part of the population and earns over US\$1 billion in foreign exchange, even though its economic importance is shrinking. Water resources are relatively abundant, but several large watersheds are already under severe water pressure; agriculture accounts for four-fifths of water demand, which is mainly met with surface water. The Yaque del Sur watershed is the third largest in the country and under enormous water stress; it is also one of the poorest areas in the Dominican Republic. Tomatoes, maize, pigeon peas, green bananas, plantains, chillies and eggplants are the main crops grown there. For the mid-term development of their region, stakeholders of the agriculture and water sector in the watershed prioritize increasing water storage capacity and irrigation efficiency, protecting water catchment areas, and improving crop productivity, soil management and education.

A tropical climate dominates in the Dominican Republic. It can rain all year, but there are clearly marked rainy and dry seasons in most parts of the country. Climate variability is mainly driven by the Intertropical Convergence Zone, Atlantic Ocean oscillations and the El Niño Southern Oscillation (ENSO), and it manifests itself in tropical cyclones and storms, heavy rainfall, floods and, to a lesser extent, droughts. Observed trends show that average temperatures have increased by about 0.45° C across the country since 1960, and rainfall has decreased by about 4.5 percent per decade, although the significance and consistency of this trend is disputed. No clear trends are available for extreme events. Climate scenarios for the national and watershed levels project continued warming of about 1° C between now and 2050, and probably decreasing rainfall. Nationwide, temperatures could increase by up to 4.2° C by the end of the century, rainfall trends are less clear but tend to be negative, and extreme events remain hard to project. Weather and climate data remain patchy and difficult to access, rendering climate information and projections, as well as risk studies, less reliable.

Almost every year, climate events claim dozens of lives, affect tens of thousands of people or cause millions of dollars in damages, and the Yaque del Sur watershed is significantly impacted by numerous climate hazards. Climate change could lead to additional stress: water scarcity will increase, so that by 2050 the annual water deficit could amount to 390 million m<sup>3</sup>, according to model results, and key crops grown in the area will require more water or see important reductions in their yields. Crops with longer growing cycles are more vulnerable, because temperature increases and precipitation reductions are concentrated in certain months. Adaptive capacity is insufficient. Irrigation committees and communities in the watershed do have strategies to cope with climate risk, but climate variability and change are increasingly overwhelming coping capacity and may make the use of sustainable coping strategies, which often require external support, less likely. The combination of hazards and vulnerability leads to significant climate risks and can jeopardize the achievement of national and sectoral development goals, including the reduction of rural poverty and inequality.

The National System for Disaster Prevention, Mitigation and Response (SNPMRD) has the National Emergency Committee, the Emergency Operations Committee and the National Technical Committee as its most important coordination bodies for different aspects of risk management; the National Council on Climate Change and the Clean Development Mechanism shares responsibility for climate change affairs with the State Secretariat for Environment and Natural Resources. The 'National Development Strategy' clearly recognizes climate risks and outlines actions for adaptation to climate change. There is no formal coordination between the disaster risk management and climate change structures, and clarity is lacking concerning responsibilities between the two agencies that deal with climate change. The Dominican Republic has a good basis for managing current climate risks, but deficiencies remain regarding vulnerability and risk assessments, prioritization of risks and risk management options, and coordination among agencies, especially between climate change adaptation and disaster risk management. Challenges also exist in terms of information management and the effective implementation of climate risk management actions.



Climate risks in the water and agriculture sectors of the Yaque del Sur watershed can be tackled through concrete actions on the ground. In a participatory process, we identified seven key strategies that can be integrated into a comprehensive risk management programme:

- Selection of adapted crop varieties (such as sorghum and mangoes) to reduce the sensitivity of crops to droughts and the projected increase in water scarcity.
- Climate-proofing of access roads, as the many unpaved roads in the area are often interrupted during extreme events, impeding market access and affecting rural incomes.
- Construction of water reservoirs for both domestic and agricultural use in the upper watershed in order to manage variations in rainfall and river run-off.
- Implementation of agroforestry systems in the upper watershed, reconciling the need for agricultural land with the benefits of a more stable and reliable downstream water supply.
- A payment for ecosystem services scheme to promote reforestation in the upper watershed and thereby reduce the risks posed by floods, droughts and water scarcity.
- An increase in irrigation efficiency from 20 percent to 45 percent, reducing water demand from agriculture by about 250 million m<sup>3</sup> annually and thereby reducing water stress.
- Better monitoring and accessibility of climate data, in order to improve short- and long-term decision-making by farmers and other stakeholders.

The present study also identified a need for further research. For example, a combination of methods similar to those used in this study could be applied in other watersheds within and outside the Dominican Republic, and the present study could be extended to include other crops, more quantitative analyses, and economic assessments on both risks and risk management strategies. Involving national experts in these efforts is crucial. On the policy level, we recommend promotion of mainstreaming climate risk into national and sectoral strategies, better coordination within and between climate risk agencies involved in disaster risk management and climate change adaptation, strengthening and facilitation of the collection and sharing of information, and strengthening of governmental capacities. A comprehensive climate risk management programme to holistically implement these recommendations should be established.

## INTRODUCTION

Climate risk management is the systematic approach and practice of incorporating climate-related events, trends and projections into development decision-making to maximize benefits and minimize potential harm or losses. Climate change is altering the nature of climate risk, increasing uncertainty and forcing us to re-evaluate conventional climate risk management practices. Historical experience with climate hazards may no longer be a sound basis for evaluating risk; observable trends and longer-term, model-generated projections must also be taken into account if development is to be truly sustainable.

Recognizing this shifting reality, UNDP, through its Bureau for Crisis Prevention and Recovery as well as the Environment and Energy Group of its Bureau for Development Policy, designed the CRM TASP to assist countries in identifying climate-related risks and risk management priorities and capacity needs as a basis for policy, planning and programme development. The International Institute for Sustainable Development (IISD) has been commissioned to implement the project in seven countries in Africa, Latin America and the Caribbean, including the Dominican Republic, in close collaboration with governments, UNDP Country Offices and other partners.

In each country, the main outputs of the project are the prioritization of climate-related risks, a focused risk assessment for a priority sector or area, and the identification of risk management options for that sector or area. This information provides an evidence base for examining the adequacy of the institutional and policy environment for implementing risk management solutions. The present report summarizes the main results of the research conducted in the Dominican Republic, where the project stakeholders chose to focus the analysis on the agriculture and water sectors in the Yaque del Sur watershed.

## APPROACH AND METHODS

Three key principles guide the implementation of the CRM TASP in each country. First, the project builds on existing climate risk information and aims to fill critical knowledge gaps. Second, the main research phase focuses on particular sectors, ecosystems or social groups in order to produce useful and concrete recommendations. Third, with a view to building capacity to identify, prioritize and manage climate risk, IISD works closely with in-country partners to execute important parts of the research. These principles are put into practice in each country through a generic six-step implementation process (see table 1).

**TABLE 1. PROJECT STEPS AND METHODS**

PROJECT STEP	PURPOSE	METHODS USED IN DOMINICAN REPUBLIC
1. Engagement	<ul style="list-style-type: none"> <li>• Raise awareness about CRM TASP.</li> <li>• Secure country-level ownership and support for process.</li> </ul>	<ul style="list-style-type: none"> <li>• Inception meetings and discussions with key stakeholders.</li> </ul>
2. Broad climate risk assessment	<ul style="list-style-type: none"> <li>• Understand and synthesize existing data and information on climate risk and risk management options.</li> </ul>	<ul style="list-style-type: none"> <li>• Literature review conducted by in-country specialists (Herrera Moreno and Orrego Ocampo, 2011).</li> </ul>
3. Risk prioritization	<ul style="list-style-type: none"> <li>• Identify gaps and priorities for climate risk assessment and management, which can be addressed in a focused risk assessment.</li> </ul>	<ul style="list-style-type: none"> <li>• National inception workshop with key stakeholders; agriculture identified as focus sector in group discussions.</li> </ul>
4. Focused climate risk assessment	<ul style="list-style-type: none"> <li>• Understand the nature of climate risk for a specific priority sector/ecosystem/social group (water and agriculture in the Yaque del Sur in the case of the Dominican Republic).</li> </ul>	<ul style="list-style-type: none"> <li>• Application of Water Evaluation and Planning (WEAP) model (Flores-Lopez, 2012).</li> <li>• Crop modelling (González Meza, 2012).</li> <li>• Community consultations based on the CRISTAL tool (González Meza et al., 2011).</li> </ul>
5. Risk prioritization II	<ul style="list-style-type: none"> <li>• Identify and prioritize climate risk management options based on the more focused assessment.</li> </ul>	<ul style="list-style-type: none"> <li>• Regional workshop based on participatory scenario development (PSD) methodology (Zamudio et al., 2011).</li> <li>• Policy and capacity analysis.</li> </ul>
6. Reporting and dissemination	<ul style="list-style-type: none"> <li>• Elaborate and validate results.</li> <li>• Secure country-level ownership of results.</li> </ul>	<ul style="list-style-type: none"> <li>• National revision workshop.</li> <li>• Publication of final report.</li> </ul>

In the Dominican Republic, the representatives of different ministries, research institutes, non-governmental organizations and international organizations chose to focus the project at the watershed level with a view to producing more specific and practical results. The main project partners specifically selected the Yaque del Sur basin because of its high levels of poverty and the impacts of past extreme climate events such as hurricanes, floods and droughts. In addition to water, agriculture emerged as a priority sector because of its high importance to local livelihoods. The National Institute for Hydrological Resources (INDRHI) became the main governmental partner for this project and formed part of the steering committee along with UNDP and IISD.

Several research tasks were undertaken. An initial **synthesis study** conducted by national specialists (Herrera Moreno and Orrego Ocampo, 2011) provided general background on climate risks and impacts. Flores-Lopez (2012) applied the **Water Evaluation and Planning (WEAP) tool** with a view to analysing the current water flows in the area and how these will be affected by future climate. This analysis was complemented with González Meza's (2012) application of the **Decision Support System for Agrotechnology Transfer crop model**, which analysed the impacts of climate change on key crop yields in the area, considering, among other things, future water availability. A team of national consultants conducted **community consultations** (González Meza et al., 2011) in different parts of the watershed to capture the perspectives of local communities and members of irrigation committees on climate hazards, impacts and coping strategies. A workshop based on the **participatory scenario development (PSD)** methodology (Bizikova et al., 2009, 2010) was held in the Yaque del Sur watershed in November 2011 to identify specific climate risk management actions that could reduce the identified risks. Some of these risk management options were subsequently modelled using WEAP in order to validate their effect on risk reduction. **Policy and capacity analysis** completed the climate risk assessment.

## KEY CONCEPTS

In this report, 'climate risk' refers to the probability of harmful consequences or expected losses resulting from the interaction of climate hazards with vulnerable conditions (UNISDR, 2004). 'Climate hazard' refers to a potentially damaging hydrometeorological event or phenomenon that can be characterized by its location, intensity, frequency, duration and probability of occurrence. This report considers both events with an identifiable onset and termination, such as a storm, flood or drought, and more permanent changes, such as a trend or transition from one climatic state to another, as hazards (Lim et al., 2005).

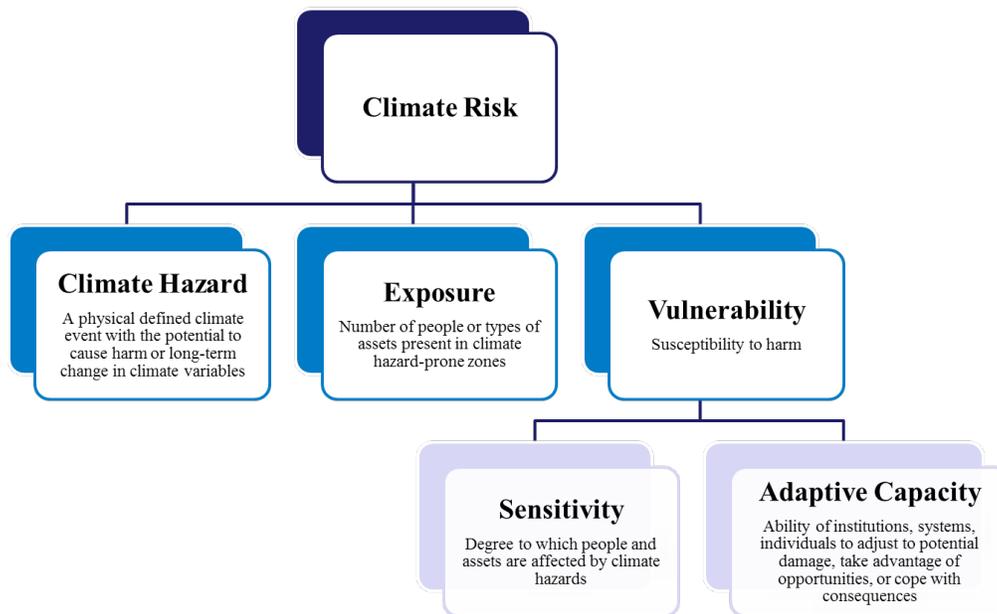


Figure 1. Components of climate risk



'Exposure' is a second element of climate risk. It refers to the presence of people and assets in areas where hazards may occur (Cardona et al., 2012). Finally, 'vulnerability' refers to the potential for a system to be harmed by something, and in the CRM TASP this 'something' is a climate hazard. When assessing vulnerability, we need to recognize the hazard specificity of people's vulnerability; indeed, the factors that make people vulnerable to earthquake are not necessarily the same as those that make people vulnerable to floods (UNDP 2004). We understand vulnerability to be a function of a system's sensitivity and its adaptive capacity, as depicted in Figure 1.

## REPORT STRUCTURE

This report has six sections. After this introduction, 'Development Profile (pp. 14–22) describes the current development conditions, trends and objectives in Dominican Republic. Particular attention is given to the agriculture and water sectors and the Yaque del Sur River basin, as this sets the baseline against which climate risks can be assessed. 'Climate Profile' (pp. 23–28), on climate conditions, variability and change, describes mainly the hazard side of the risk equation. Next, 'Climate Impacts and Risks (pp. 29–36) provides a detailed analysis for the water and agriculture sectors in the Yaque del Sur watershed, building on the various primary research tasks described above. 'Institutions and Policies for Climate Risk Management' (pp. 37–40) looks at the institutions, policies and initiatives that exist currently to deal with climate impacts and risks. Finally, 'Recommendations for Climate Risk Management' (pp. 41–47) lists actions to reduce the risk of negative impacts on the watershed, changes to institutions and policies needed to facilitate such actions, and directions for further research.

## DEVELOPMENT PROFILE

The general development conditions of a country play an important role in determining climate risk, particularly the vulnerability of its sectors. Agriculture and water resources, for instance, are much more sensitive to climatic conditions than many other sectors, and are intrinsically linked. Factors like income or social capital are key elements of adaptive capacity, and can explain in part how well people can deal with climate hazards. This section lays the basis for the subsequent risk analysis by summarizing development conditions, trends and challenges, as well as the vision, objectives and priorities for future development. Trends and conditions in the water and agriculture sectors and in the Yaque del Sur watershed are given particular attention.

## NATIONAL DEVELOPMENT CONDITIONS, TRENDS AND CHALLENGES

The Dominican Republic occupies the eastern two-thirds of the Island of Hispaniola, the other third of which is occupied by Haiti, and lies between the Caribbean Sea and the North Atlantic Ocean. The country's territory of 48,442 km<sup>2</sup> makes it the second-largest country in the Antilles, after Cuba. The Dominican Republic is divided into three main geographic regions: the northern part of the country, called 'Cibao,' the South and the Southeast. The country is administratively divided into 31 provinces and the National District, where the capital, Santo Domingo, is located. The provinces are in turn subdivided into municipalities (see map below).



Figure 2. Map of the Dominican Republic (reprinted with permission from [DominicaOnline.org](http://DominicaOnline.org))<sup>1</sup>

In 2011 an estimated 10,056,000 people lived in Dominican Republic, with the population concentrated in the cities as a result of internal migration. This migration started in 1960 and has led to a rapid urban expansion, especially towards the two main cities of Santo Domingo and Santiago (World Bank, 2011a; Herrera Moreno and Orrego Ocampo, 2011). The share of the urban population has risen from 56 percent in 1991 to 69.8 percent in 2011 (World Bank, 2011b; UNDP, 2011a). Current population growth is estimated at 1.33 percent in 2011 (Central Intelligence Agency, 2011), and population is expected to reach between 11.0 and 15.1 million people in 2050, according to United Nations (2012a) estimates. The share of the population living in rural areas is likely to continue to decline (Population Reference Bureau, 2011).

<sup>1</sup> The boundaries and names shown on the maps in this report do not imply official endorsement or acceptance by the United Nations.

## Poverty and human development

Income per capita in purchasing power parity was US\$8,960 in 2010. Just over one-third (34.4 percent) of the population lived in poverty in 2010, down from a peak of 43.4 percent in 2004, but up from only 28.2 percent in 2000. (World Bank, 2012). What's more, almost 20 percent of the population lived in extreme poverty in 2009 (IFAD, 2011). Income distribution in the country is highly skewed, and it is estimated that the richest 10 percent of the population receives over 37 percent of the total income, 18 times more than that received by the most impoverished 10 percent of the population (Winslow, 2011). The Dominican Republic had an income Gini coefficient, a measure of inequality where a higher number means greater inequality, of 48.4 in 2011, which remains below the average in Latin American and Caribbean countries of 50.41<sup>2</sup> and that of its neighbour, Haiti, of 59.5 (UNDP, 2011a).

Despite a significant increase in the proportion of children reaching the last year of primary school, from 23.2 percent in 1990 to 75.8 percent in 2009, and a relatively high literacy rate among 15- to 24-year-olds (96.9 percent in 2009), the second United Nations Millennium Development Goal (MDG) of achieving a 100 percent full course of primary schooling for all children by 2015 is unlikely to be reached due to high levels of desertion. Moreover, even though the enrolment rate in primary school keeps increasing (from 84.1 percent in 1999 to 90.3 percent in 2008), the quality of education remains a critical issue, and the median years of schooling in 2011 (7.2 percent) remains below the regional average (7.7 percent) (MEPyD, 2010b; UNDP, 2011a).

Women, indigenous populations, people of African descent and people of Haitian origin are the groups hardest hit by inequality. Nevertheless, important improvements have occurred in gender equity in terms of access to education, where the old patterns are now being reversed, with more girls (49.7 percent of people 25 years old and older) receiving secondary education than boys (41.8 percent) (MEPyD, 2010b; UNDP, 2011a). Yet even though both the proportion of women with paying jobs outside the agricultural sector and the share of women in Congress (19.1 percent in 2011 against 11.7 percent in 1990) have increased, they remain far from achieving full equality (MEPyD, 2010b; UNDP, 2011a).

Twenty-one percent of the population suffered from malnutrition in 2005. Part of the first MDG is to reduce malnutrition to 13.5 percent of the population by 2015, which, according to the Dominican Government, seems unlikely to be reached. Nevertheless, the prevalence of underweight children under five years of age has decreased by more than half since 1990 (MEPyD, 2010b). Child mortality dropped from 47.8 out of 1,000 live births in 1990 to 22.3 ten years later. For infant mortality, the rate dropped from 54.5 in 1993 to 26.10 in 2010, but remains above the regional average (World Bank, 2011b). Eighty percent of infant mortality is explained by a very high maternal mortality ratio of 100 per 100,000 live births in 2008, despite a reduction of more than half since 1990 (World Bank, 2011a). Hence, the fifth MDG to reduce the maternal mortality ratio to 46.9 in 2015 remains unattainable, due notably to poor-quality health services (MEPyD, 2010a). Life expectancy (73.40) is similar to the Caribbean average. HIV rates have not yet been reversed, but, according to national statistics, this could still be achieved by 2015 (MEPyD, 2010b). The prevalence of malaria and tuberculosis has increased since 1990. For malaria, the rate has jumped from 5.0 per 100,000 inhabitants in 1990 to 16.8 in 2009, instead of the reduction stipulated by the sixth MDG.

The Dominican Republic has, however, improved conditions related to water and sanitation. Of all households, 86.1 percent had access to improved water sources in 2007, up from 66.4 percent in 1991. The share of dwellings with access to basic sanitation increased from 61.1 percent to 82.7 percent over the same period (MEPyD, 2010b). The country has also increased its proportion of protected areas at the national level as part of the seventh MDG of ensuring a sustainable environment (MEPyD, 2010b).

UNDP's Human Development Index (HDI) summarizes the development state of countries by ranking them according to life expectancy, schooling and income. The Dominican Republic currently ranks 98, slightly lower than the regional average but much higher than its neighbour, Haiti (ranked 158; see table 2).

<sup>2</sup> This average was calculated from the countries with available data for the period from 2000 to 2011 (UNDP, 2011a).

**TABLE 2. HUMAN DEVELOPMENT INDEX VALUES FOR SELECTED COUNTRIES AND REGIONS (UNDP, 2011A)**

COUNTRY	HDI RANK (2011)	HDI VALUE (2011)	LIFE EXPECTANCY (YEARS, 2011)	MEDIAN YEARS OF SCHOOLING (2011)	EXPECTED YEARS OF SCHOOLING (2011)	GROSS NATIONAL INCOME PER CAPITA (CONSTANT 2005 PPP USD)
Dominican Republic	98	0.689	73.40	7.20 <sup>a</sup>	11.90	8,087
Cuba	51	0.776	79.10	9.90	17.50	5,416
Haiti	158	0.454	62.10	4.90	7.60 <sup>b</sup>	1,123
<i>Caribbean Average</i>	<i>78.50</i>	<i>0.720</i>	<i>73.39</i>	<i>8.38</i>	<i>13.24</i>	<i>10,091</i>
<i>Central American Av.</i>	<i>95.38</i>	<i>0.68</i>	<i>74.88</i>	<i>7.26</i>	<i>12.01</i>	<i>7,232</i>
<i>South American Av.</i>	<i>81.67</i>	<i>0.72</i>	<i>73.57</i>	<i>8.17</i>	<i>13.73</i>	<i>8,810</i>

a: Data refer to 2011 or the most recent year available.

b: Refers to primary and secondary education only.

## Economy and politics

The Dominican Republic is a middle-income developing country. Its GDP amounted to US\$51.6 billion or US\$5,195 per capita in 2010, valued at market exchange rates (World Bank, 2011b). GDP has grown strongly in recent years, despite the country experiencing a significant economic slowdown during the global economic crisis, from which growth quickly recovered (World Bank, 2011a; IFAD, 2011). Following a period of high growth averaging 9.5 percent (2005 to 2007), economic activity began to slow, to 5.3 percent in 2008 and to 3.5 percent in 2009 (World Bank, 2011a). The economy bounced back in 2010, with a 7.8 percent annual growth rate (World Bank, 2011a).

Once heavily based on sugar and other agricultural exports, the Dominican Republic's economy is more diversified today. Tourism, telecommunications and free trade zones are now its main drivers (IFAD, 2011; Winslow, 2011). Consequently, the agricultural sector's share of GDP has declined to 5.5 percent in 2010; industry contributed 27.3 percent and the service sector, 64.6 percent (CIA, 2011; World Bank, 2011b). Tourism accounts for nearly US\$1.5 billion in annual earnings and is, together with industries in free trade zones, the fastest-growing export sector (Winslow, 2011).

The Dominican Republic is a representative democracy. President Leonel Fernández was re-elected in 2008 for a third non-consecutive term (World Bank, 2011a). Despite a stable political situation and relatively high economic growth, the gap between rich and poor has increased, and the people have low levels of trust in the government (Patterson, 2004).

## Environment

Deforestation, soil degradation and the deterioration of water resources are some of the most important environmental issues in the Dominican Republic (UNEP, 2010). After a century of deforestation, the forest cover has increased again, from 28.4 percent in 1990 to 32.6 percent in 2003, and the size of protected areas has been expanding (IFAD, 2011). However, forest degradation continues, as a result of expanding agriculture and tourism as well as forest fires. Fifty-two percent of the country's land area is estimated to be highly susceptible to soil erosion. Furthermore, pressures on the surface and subsurface waters are increasing, due to population increase and the expansion of economic activity (UNEP, 2010).

## NATIONAL DEVELOPMENT VISIONS, OBJECTIVES AND PRIORITIES

In 2010 the Government adopted its 'National Development Strategy' (MEPyD, 2010a) presenting the country's development vision for the period from 2010 to 2030. The strategy represents the conceptual framework for all public policies to be implemented during that period, and will be operationalized through the tools of the National Planning and Public Investment System. It has four strategic axes: institutions; poverty, education and health; sectors contributing to the economy; and environmental sustainability.

To evaluate progress in the implementation and achievement of these strategic axes, a set of indicators and qualitative and quantitative development objectives, as well as a monitoring and evaluation system, were set up as part of the same national strategy. Table 3 presents the strategic themes and sample indicators for each of them, as well as their target values for 2020 and 2030.

**TABLE 3. STRATEGIC AXES OF THE 'NATIONAL DEVELOPMENT STRATEGY' AND SAMPLE PROGRESS INDICATORS (MEPYD, 2010A)**

NATIONAL DEVELOPMENT STRATEGIC AXES AND SAMPLE PROGRESS INDICATORS	TARGET FOR 2020	TARGET FOR 2030
<b>Strategic axis 1: A State with efficient and transparent institutions, at the service of a responsible and participative citizenry, which guarantees security and promotes development and peaceful cohabitation.</b>		
Corruption Perception Index (from 0 to 10, with lower values corresponding to higher perceptions of corruption)	5.1 (up from 3.0 in 2008)	7.8
Institutional Robustness Index (from 1 to 7, with higher value meaning higher robustness)	4.5 (up from 3.1 in 2008)	6.1
Number of homicides/100,000 inhabitants	4.2 (down from 24.4 in 2006)	1.2
<b>Strategic axis 2: A cohesive society with equal opportunities and low levels of poverty and inequality.</b>		
Proportion of the population living in moderate poverty	22% (down from 36.5% in 2008)	15%
Proportion of the rural population living in moderate poverty	26.5% (down from 50.9% in 2008)	under 20%
Gini coefficient of income inequality (higher values correspond to greater inequality)	46 (down from 50.4 in 2008)	42
Enrolment in primary education	100% (up from 94.9% in 2007)	100%
Life expectancy at birth (years)	77 (up from 72 to 74 in 2005–2010)	80
Access to clean water (% of population)	100% (up from 95% in 2006)	100%
Seats in senate (% female)	33% (up from 6.3% in 2006)	50%
<b>Strategic axis 3: An integrated economy, innovative and environmentally sustainable, with a productive structure that generates high and sustained growth through decent employment and integrates itself in a competitive way into the global economy.</b>		
Internet users (per 100 inhabitants)	60 (up from 25.8 in 2008)	80
Share in global market for export goods (%)	0.1% (up from 0.049% in 2006–2008)	0.17%
Share in global market for export of agricultural and livestock products (%)	0.096% (up from 0.061% in 2006–2007)	0.13%
<b>Strategic axis 4: Sustainable management of the environment and adequate adaptation to climate change.</b>		
National protected areas (% of total territory)	24.4% (as in 2006)	24.4%
Average annual deforestation rate	–0.2% (down from 0.1% in 2005)	–0.2%

In addition, the strategy also proposes non-quantitative objectives. For example, it aims to reduce gaps in access to basic services and economic opportunities between urban and rural areas, as part of strategic axis 2. Under axis 3, the productivity, competitiveness, and environmental and financial sustainability of agricultural value chains are to be improved, so as to create exports, employment and rural incomes and to ensure food security. The last axis also includes the protection and sustainable exploitation of natural

resources, improvements in environmental quality, efficient and sustainable management of water resources, the development of an efficient and integrated national risk management system within 10 years, and the promotion of adaptation to and mitigation of climate change, including the establishment of construction norms for climate-proof infrastructure by 2015.

Several goals of the strategy are aligned with the MDGs. For example, the second strategic axis coincides with the first MDG, as it aims to reduce poverty and malnutrition levels. It also aims to achieve universal primary and secondary education, aligning it with the second MDG, as well as increase access to health services, reduce gender disparities, reduce child and maternal mortality and improve access to sanitation and potable water, aligning it with the third, fourth, fifth and sixth MDGs, and some sub-objectives of the seventh. Its third axis aligns it with some of the eight MDG, as it aims to increase access to technology, information and communication. Finally, its fourth axis is in line with the seventh MDG, aimed at ensuring environmental sustainability (UN, 2012b).

## AGRICULTURE, WATER AND THE YAQUE DEL SUR BASIN

This subsection details some of the conditions, tendencies and development priorities in the two focus sectors—agriculture and water—and in the Yaque del Sur watershed.

### Agriculture

The share of agriculture (including forestry, hunting, fishing and livestock) in GDP has declined over recent decades, to 5.5 percent in 2010 from 11.2 percent in 1993 (World Bank, 2011b). Crop farming accounts for about 55 percent of the country's agricultural output, livestock for 40 percent, and forestry and fishing for 5 percent. In recent years, increased financial support from the government, the private sector and international development agencies has helped diversify and stimulate this sector (IFAD, 2011). Total agricultural output exports in 2009 were worth US\$1.016 billion. The main crops according to area, production and value are shown in table 4 below. From these, the most important foreign exchange earnings in 2011 came from bananas, cocoa beans, plantains and green coffee (FAO, 2011).

**TABLE 4. KEY CROPS IN DOMINICAN REPUBLIC, 2011 (DATA SOURCE: FAO, 2011)**

CROP/FRUIT	HARVESTED AREA (HA)	PRODUCTION (T)	VALUE (USD)*
Avocadoes	9,546	184,400	59,800,920
Bananas	23,500	589,500	71,624,250
Beans, dry	33,745	30,603	91,037,804
Chillies and peppers, green	7,495	37,831	25,494,311
Cassava	21,464	165,688	58,438,158
Cocoa beans	173,000	50,200	88,276,700
Coffee, green	130,000	39,000	68,581,500
Eggplant	3,766	23,938	7,870,814
Maize	23,887	35,037	13,037,268
Mangoes, mangosteens, guavas	27,232	257,904	39,923,539
Oil palm fruit	12,300	188,800	n/a
Oranges	8,700	128,800	16,834,160
Pigeon peas	24,782	26,306	16,530,690
Pineapple	8,808	127,200	25,910,640
Plantains	43,000	517,271	122,541,500
Rice, paddy	182,012	551,365	449,362,475
Sugar cane	84,000	4,716,170	129,223,058
Tomatoes	7,100	234,498	189,404,035

\* This value has been estimated by multiplying production quantities with 2009 prices per ton.

The agriculture sector provided work to about 14.5 percent of the population in 2007, down from 20.3 percent in 1991 (World Bank, 2011b). The sector remains essential to meet the nutritional needs of the country's population. Moreover, the country has recently become an important exporter of niche agricultural products such as organic coffee, organic cacao and bananas. As a result of an increase in non-traditional crops and organic products, a growing number of medium- and small-scale farmers are taking up the production of these special crops, and this is changing the agricultural profile of the country (IFAD, 2011). The Dominican Republic now has 14,000 organic growers and is the third-largest Latin American exporter of organic products, after Mexico and Peru.

The agrarian structure remains very unequal, with land tenure highly concentrated in the hands of a small proportion of producers. Just over 6 percent of agricultural producers control about 70 percent of agricultural land, and about 80 percent of farmers own less than 8 percent of the land. Additionally, 40 percent of these 80 percent are small-scale producers (working between 0.5 and 2.0 hectares) (IFAD, 2011).

The Government's overall goals for the agricultural sector are summarized in the 'National Development Strategy' (MEPyD, 2010a), which aims to improve the productivity, competitiveness, and environmental and financial sustainability of agricultural value chains with a view to increasing exports, employment and rural incomes and ensuring food security. These goals will be achieved through 14 guidelines for action, which include institutional reform; crop and land-use planning; promotion of practices for sustainable natural resource management; promotion of climate-resilient and biodiversity-friendly crops; research, technological development and innovation; access to information and market intelligence through the use of information technology; associative structures and alliances; finance and insurance mechanisms; systems to ensure health and hygiene; provision of infrastructure and services; export support; promotion of cultures and species with high market potential; and assignment of land titles, with the establishment of a registry for these titles.

## Water

According to the European Commission's Humanitarian Aid and Civil Protection department's 'Disaster Preparedness Programme' (DIPECHO) (2009), the Dominican Republic had water resources of 13,205 million m<sup>3</sup> in 2000, of which 4,865 million m<sup>3</sup> were used. Water caught from rivers was mainly used for irrigation (79 percent) and, to a much lower extent, for industry (2 percent), fishing (1 percent) and drinking (1 percent). Water for irrigation predominantly comes from surface water (83 percent), caught directly from rivers or stored in reservoirs, while only 17 percent came from groundwater (González Meza and Mena, 2011). The Dominican Republic has four main slopes, as per its orography: the Caribbean Sea, the Atlantic Ocean, Haiti and the El Enriquillo salt lake. These four regions can be further divided into 14 main river basins (see figure 3) (DIPECHO, 2009).

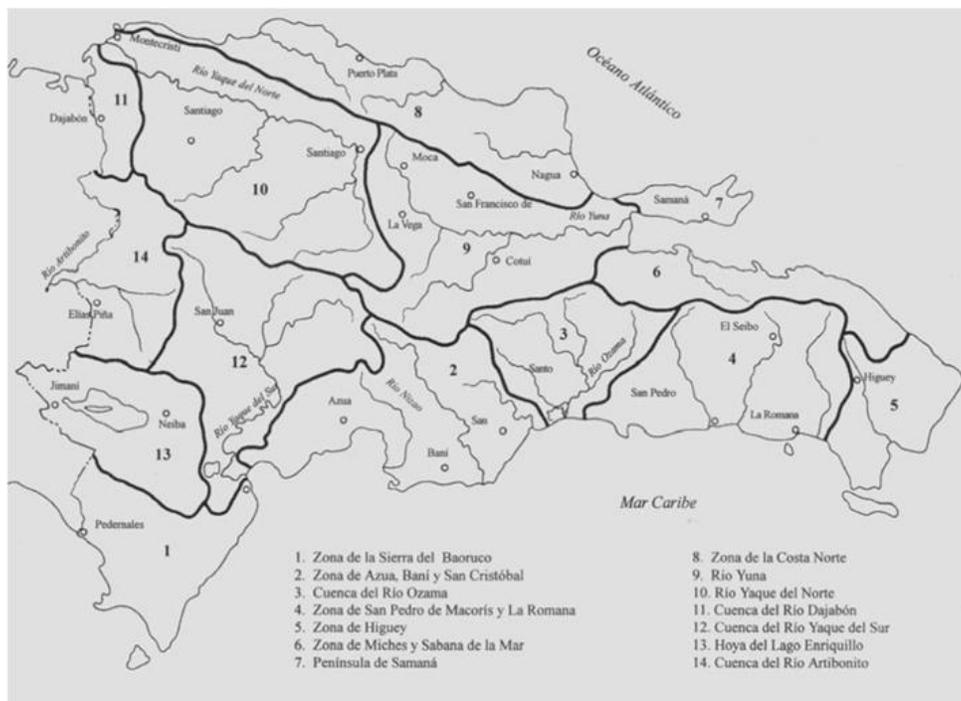


Figure 3. Main watersheds in the Dominican Republic (modified from DIPECHO, 2009)

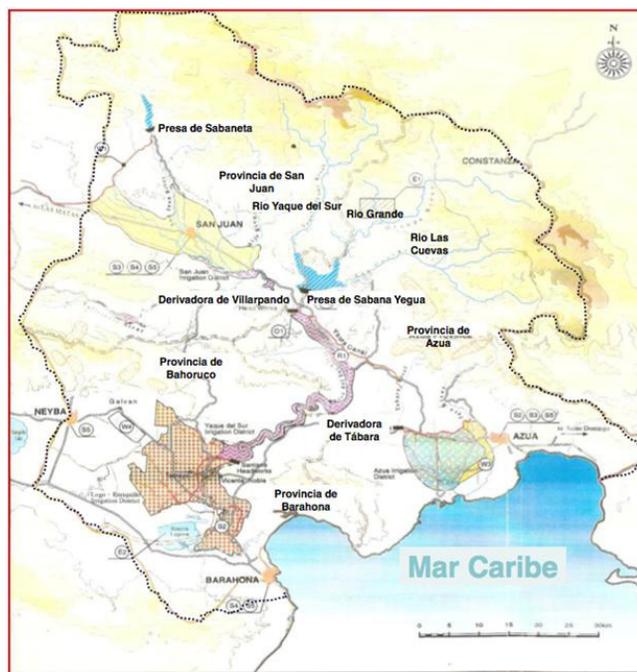
Water availability varies depending on the region. The Southeast, including the Yaque del Sur River basin, has the highest availability of water, but is also the region where water resources are most under pressure (see table 5). Table 5 shows water availability and pressure in key watersheds.<sup>3</sup>

**TABLE 5. PRESSURE ON WATER RESOURCES BY REGION (MODIFIED FROM WORK ORIGINALLY PUBLISHED IN GONZÁLEZ MEZA AND MENA, 2011)**

WATERSHEDS	AVAILABILITY	DEMAND	EXCESS	HYDROLOGICAL PRESSURE (DEMAND/SUPPLY)	DEGREE
				PERCENTAGE	
Yaque del Sur	4,268.0	3,671.05	596.95	86%	Strong
Yaque del Norte	4,210.0	2,796.78	1,413.22	66%	Strong
Atlantic	2,386.0	390.46	1,995.54	16%	Moderate
Yuna	3,085.0	1,194.65	1,890.35	39%	Medium
Ozama-Nizao	3,802.0	1,200.53	2,601.47	32%	Medium
East	1,649.0	319.63	1,329.37	19%	Moderate
<b>Total</b>	<b>19,400.0</b>	<b>9,573.10</b>	<b>9,826.90</b>	<b>49% (average)</b>	

### Yaque del Sur River basin

The Yaque del Sur River watershed is located in the southeastern part of the Dominican Republic and overlaps with six provinces, of which Bahoruco, Azua, San Juan and Barahona are the main ones. Twenty-nine municipalities and 150 rural sections lie in the area, which is considered one of the least developed regions of the country. As all watersheds, the Yaque del Sur has its sources in the Cordillera Central mountain range massif. It then flows to the south, into the Caribbean Sea at the Bahía de Neiba. It has an area of 7,100 km<sup>2</sup>, or 14 percent of the national territory,<sup>4</sup> and is the third-largest watershed in the country, after Yaque del Norte and Yuna (González Meza, 2010).



*Figure 4. General map of the Yaque del Sur Watershed (originally published in González Meza, 2010)*

<sup>3</sup> Different studies use different area delimitations. The values for the Yaque del Sur watershed differ from results used later in this study, most likely because of differences in the delimitation of the area. The figures in table 5 likely refer to an area that is larger than the Yaque del Sur river basin proper.

<sup>4</sup> 5,345 km<sup>2</sup> according to DIPECHO (2009), and 5,096 km according to UNDP (2009).

The Yaque del Sur River runs through 209 km, compared with 296 km for the Yaque del Norte River, and is fed mainly by the Mijo, Medio, Las Cuevas, Los Baos and San Juan rivers. The Sabana Yegua dam is the second-largest in the country, with a capacity of 560 billion m<sup>3</sup>, and is located in the middle of the watershed (DIPECHO, 2009). Five other dams are in the area, including the Sabaneta dam. This infrastructure currently meets 13.1 percent of the total demand in the area (3,671 million m<sup>3</sup>), according to INDRHI's most recent figures. Most irrigation occurs in the lower watershed. The four areas of Azua, Padre las Casas, San Juan and Barahona contain 47,139 hectares of irrigated land that use 1,436.77 million m<sup>3</sup> of water with an average efficiency of 22 percent (González Meza and Mena, 2011).

The main crops grown in the Yaque del Sur watershed are tomatoes, maize, pigeon peas, green bananas, plantains, chillies and eggplants. Crop yields mainly depend on temperature and rainfall. Table 6 shows some of the major crops cultivated in this river basin and their water needs according to standards of the Food and Agriculture Organization (FAO) of the United Nations (González Meza, 2010).

**TABLE 6. WATER DEMAND FOR MAIN CROPS (ORIGINALLY PUBLISHED IN GONZÁLEZ MEZA, 2010)**

CROP	CULTIVATED AREA (HA)	CROP WATER NEED (MM/ AGRICULTURAL CYCLE OR GROWING SEASON)	TOTAL CROP WATER NEED (M <sup>3</sup> ) PER SEASON
Maize	9,256.8	390	36,101,520
Plantains	2,216.3	1,713	37,964,941
Pigeon peas	1,239.4	1,168	14,475,725
Tomatoes	666.0	393	2,617,380
Bananas (green)	610.7	1,713	10,461,976
Chillies	453.8	583	2,645,654
Eggplants	241.8	607	1,467,726

In a participatory scenario development (PSD) workshop held in the city of Barahona in the Yaque del Sur watershed, stakeholders of the agriculture and water sectors identified a number of development goals for the upper and lower watershed that are to be achieved by the year 2025, along with an assessment of the current situation and possible steps to achieve the goals. Table 7 summarizes the goals, current situation and steps and shows that many concerns, such as market access, deforestation, soil degradation, water scarcity and education are shared between both parts of the watershed. However, stakeholders from the upper watershed have put more emphasis on sustainable soil use and compensation mechanisms for the protection of water catchment areas, whereas for the lower watershed, hydrological infrastructure, including dams and irrigation, as well as agricultural productivity itself are key priorities.

**TABLE 7. DEVELOPMENT GOALS FOR THE UPPER AND LOWER WATERSHEDS (ORIGINALLY PUBLISHED IN ZAMUDIO ET AL., 2011)**

GOAL FOR 2025	CURRENT SITUATION	KEY STEPS TO ACHIEVE GOAL
<b>LOWER WATERSHED</b>		
Increased water storage capacity	Dams and lakes that are full of sediment due to deforestation of basin	Extraction of sediment; construction of new dams; reforestation of upper watershed
Increased irrigation efficiency at farm level	60% loss of water flow due to infiltration and weak management	Construction of canals and control works
Increased agricultural productivity	Limited technology and low investment, leading to low productivity	Technology improvements; better access to finance; reform of the market system
Guaranteed markets for products	Lack of markets and low producer prices	More integration of farmers in associations; creation of agribusiness centres
Increased general and specific education levels of water users	Low education levels; lack of incentives to study	More investments in education; capacity development
<b>UPPER WATERSHED</b>		
Adequate soil use by 60% of farmers	Adequate soil use practiced by only 20% of farmers	Soil studies; credits for farmers; implementation of compensation mechanisms between lower and upper watershed; better incentives
Access to fair markets for 80% of farmers	Dependency by most farmers on intermediaries; exposure to price instability	Identification of niche markets; strengthening of associations; increased capacity to commercialize produce
Protection and conservation of 100% of water sources	Protection of only 50% of all sources	Limitation of agricultural frontier in water catchment areas
Implementation of compensation mechanism to promote water catchment area conservation	A fund that is about to be set up	Capitalization of the fund; definition and operation of the compensation mechanisms
Literacy for 95% of the population	Literacy for only 64% of the population	Implementation of literacy programmes; alliance between education ministry and non-governmental organizations (NGOs)

### Key messages: Development profile

- The Dominican Republic is an upper-middle-income country, yet good average income levels hide development challenges such as insufficient education and health and high gender and income inequality.
- Although the economic importance of agriculture is shrinking, the sector still provides employment to a large part of the population and earns over US\$1 billion in foreign exchange.
- Water resources are relatively abundant overall, but several large watersheds are already under severe water pressure. Agriculture accounts for four-fifths of water demand, which is mainly met with surface water.
- The Yaque del Sur watershed is the third-largest in the country and under enormous water stress; it is also one of the poorest areas in the Dominican Republic. Tomatoes, maize, pigeon peas, green bananas, plantains, chillies and eggplants are the main crops grown there.
- The 'National Development Strategy' aims to strengthen good governance, reduce poverty and inequality, and pursue economic integration and environmental sustainability. It also aims to increase the productivity, competitiveness, and environmental and financial sustainability of agricultural value chains with a view to increasing exports, employment and rural incomes, and to ensuring food security.
- For the future development of their region, stakeholders of the agriculture and water sectors in the watershed prioritize increasing water storage capacity, increasing irrigation efficiency, the protection of water catchment areas, improving crop productivity, and improving soil management and education.

## CLIMATE PROFILE

As a tropical country, the Dominican Republic experiences year-round warm and humid conditions. Yet the country's topographic heterogeneity means that local climates vary significantly, ranging from arid to wet. Temperatures average from 26° C to 28° C in the lowlands and from 18° C to 22° C in higher altitudes. The hottest months are June, July and August, while December to February is the coldest period (DIPECHO, 2009; SEMARENA and UNDP, 2009). Rain falls all year, yet in most of the country there is a dry season from December to March and a wet season from May to November. In the Septentrional mountain range, in the middle of the country the wettest period extends from November to January due to the influence of trade winds (DIPECHO, 2009; McSweeney et al., 2009). Annual average rainfall amounts to about 1,500 mm, but varies from 350 mm in the driest zone to 2,743 mm in the wettest zones (SEMARENA and UNDP, 2009). According to the National Meteorological Office (2011), May, August, September and October are the months with the most precipitation in the Southwest, where the Yaque del Sur River basin is situated.

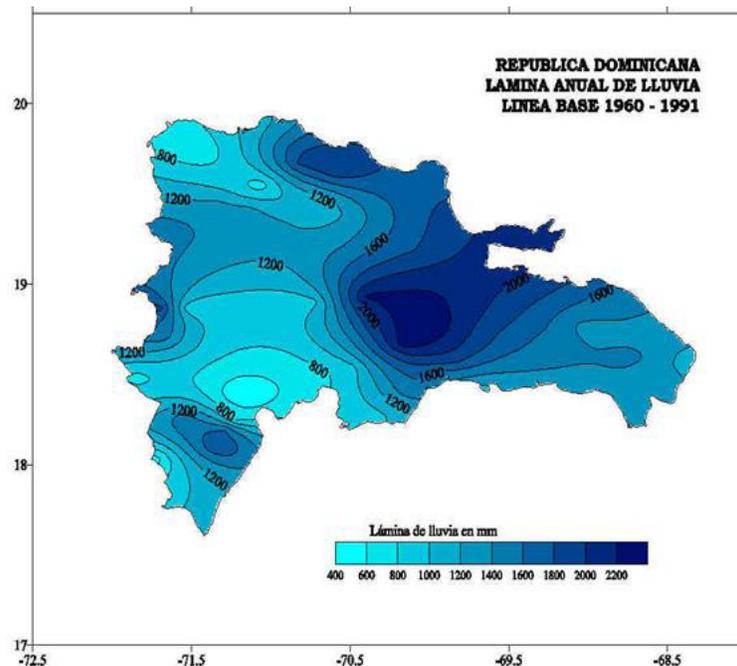


Figure 5. Average annual rainfall, 1960 to 1991 (reprinted with permission from Planos, 2001)

## CURRENT CLIMATE VARIABILITY AND EXTREMES

Important deviations from the average climate have been observed in the Dominican Republic, especially during the rain and cyclone season, including climate hazards such as heavy rainfall, tropical storms and cyclones, floods, and droughts.

Climate variability in the Dominican Republic is mainly driven by the Intertropical Convergence Zone, the Atlantic Meridional Mode, the Atlantic Multidecadal Oscillation and the El Niño Southern Oscillation (ENSO). The Intertropical Convergence Zone is a worldwide band where northern and southern trade winds come together and force air up into the atmosphere. Most tropical storms and cyclones are formed there (National Aeronautics and Space Administration, 2011). ENSO is a climate pattern characterized by changes in ocean surface temperatures and pressure in the tropical eastern Pacific. Warm deviations are called El Niño, whereas cold deviations are called La Niña (Klotzbach, 2011). El Niño phases are thought to cause droughts, especially in arid regions (SEMARENA and UNDP, 2009), and may neutralize cyclonic activity in the northern Atlantic and Caribbean during the summer hurricane season (Grogg, 2009; Klotzbach, 2011). La Niña, on the other hand, seems to be a driver of tropical cyclones in the Caribbean (McSweeney et al., 2009), as are positive phases of the Atlantic Multidecadal Oscillation and Atlantic Meridional Mode, which cause sea surface temperatures to increase and vertical wind shear to decrease (Klotzbach, 2011).

The Dominican Republic's geographic location in the centre of the Greater Antilles archipelago, in the Caribbean region, exposes it to recurrent tropical cyclones originating in the Atlantic Ocean and the Caribbean Sea. Hurricanes usually hit the country on its southwest and southeast coasts (DIPECHO, 2009). Tropical cyclones generally develop during the rainy season, with the peak occurring between August and October (SEMARENA and UNDP, 2009). According to past records, more than 100 tropical storms or cyclones affected the Dominican Republic between 1971 and 2008 (DIPECHO, 2009 see figure 6). These include many severe events, as impact statistics demonstrate in the next section.



Figure 6. Map of exposure\* to tropical cyclones (DIPECHO, 2009)  
\*Red stands for 'very high' and orange for 'high.'

Floods are the most frequent climate-related hazard in the Dominican Republic. They are caused by tropical storms and cyclones, heavy rains caused by cold fronts, tropical waves, or other climate phenomena, as well as by local conditions such as small riverbeds (DIPECHO, 2009). The regions in the Dominican Republic most exposed to flooding are the Yaque del Norte, Yaque del Sur, Yuna and Soco watersheds, as well as marginal zones alongside rivers in the cities of Santo Domingo and Santiago (see figure 7). Heavy rains are also suspected to contribute to increasing water levels in the below-sea-level lakes Enriquillo and Saumâtre (Herrera Moreno and Orrego Ocampo, 2011).

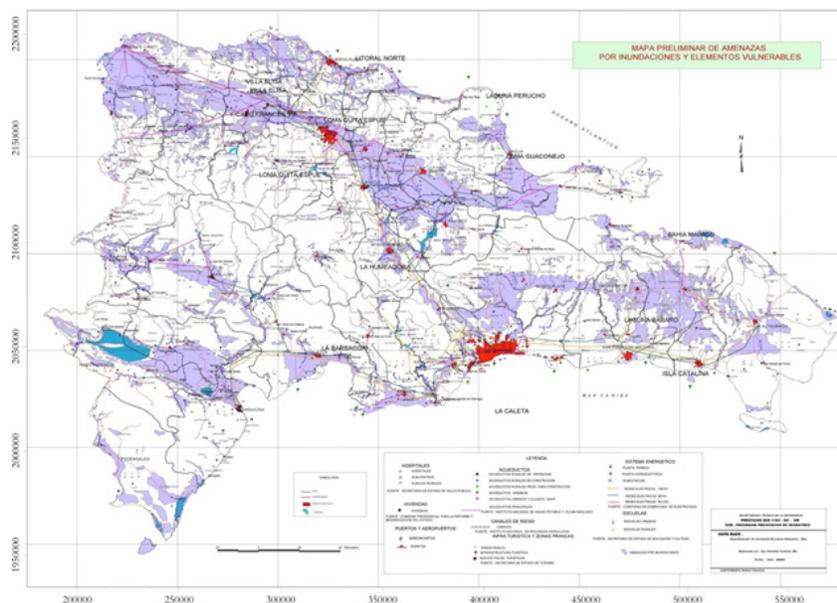


Figure 7. Flood-prone zones\* (Inter-American Development Bank, 2010)  
\*Purple areas are considered flood prone

Landslides are largely associated with heavy rain and floods. The most exposed regions are the mountain ranges in the Cordillera Central and Cordillera Septentrional, as well as the Neiba and Bahoruco areas and the hills of the Samaná Peninsula (DIPECHO, 2009).

Sixty-nine percent of the Dominican territory is thought to be arid, semi-arid and dry subhumid zones, which are completely or partially affected by droughts and desertification (Herrera Moreno and Orrego Ocampo, 2011). Figure 8 shows an aridity map of the country. According to this map, the most arid areas lie in the northwestern provinces of Monte Cristi and Valverde, as well as in the southwestern provinces of Independencia, Baoruco, Azua and parts of San Juan and Peravia. Droughts are associated with El Niño phenomena and are seen as the fifth-most-important disasters to have impacted the country between 1966 and 2000 (DIPECHO, 2009). However, very little data on droughts are available.

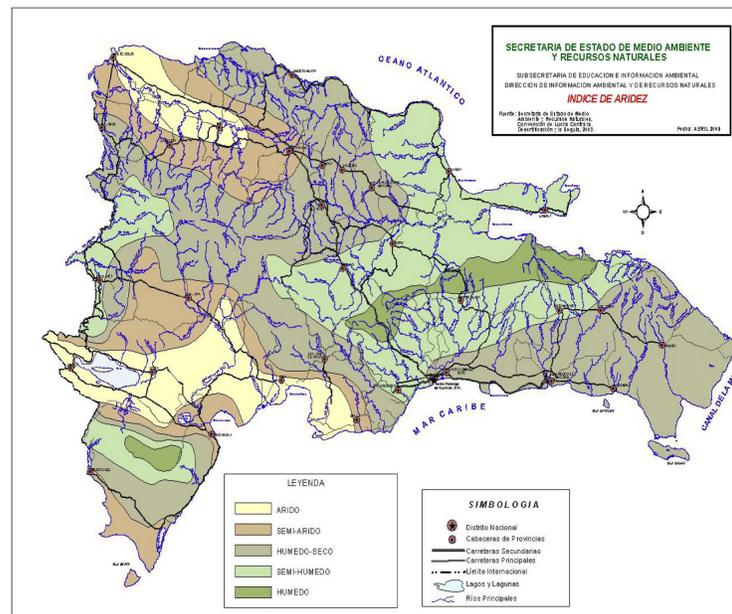


Figure 8. Aridity map\* (reprinted with permission from SEMARENA, 2006)  
\*Legend: yellow depicts arid areas, brown semi-arid areas

Other hazards include forest fires, which have become an important hazard to forests and endemic fauna and flora in the Dominican Republic. A relatively less well-known phenomenon is one provoking waves to arrive in the opposite direction from their normal direction towards the coast, which has significant impacts on coasts and beaches (Herrera Moreno and Orrego Ocampo, 2011).

## OBSERVABLE CHANGES IN CLIMATE

Mean annual temperature has increased by around 0.45° C since 1960. In line with this, the frequency of hot days and nights—that is, where average temperatures are exceeded by 10 percent or more—has significantly increased since 1960, mainly during the warmest seasons, while the number of cold days and nights has decreased (McSweeney et al., 2009).

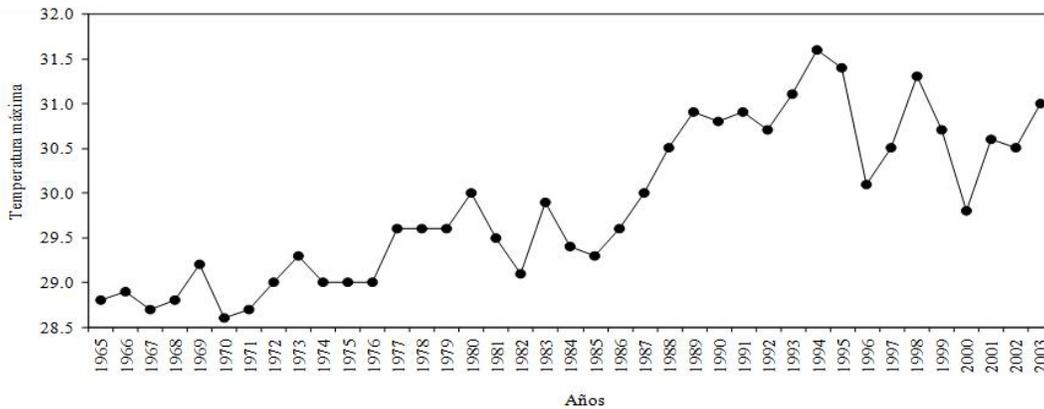


Figure 9. Maximum temperatures in Punta Cana from 1965 to 2003 (reprinted with permission from SEMARENA and UNDP, 2009)

The increase has been stronger in some areas than in others. Figure 9 shows that in the eastern Punta Cana area, maximum temperatures are now about 2 degrees higher than they were around 1970. González Meza (2010) has conducted a statistical analysis on temperature data from several weather stations across the country, finding that in seven out of fifteen stations, the period 1986 to 2004 was significantly warmer than 1968 to 1985. Some of these stations are located in the Yaque del Sur watershed.

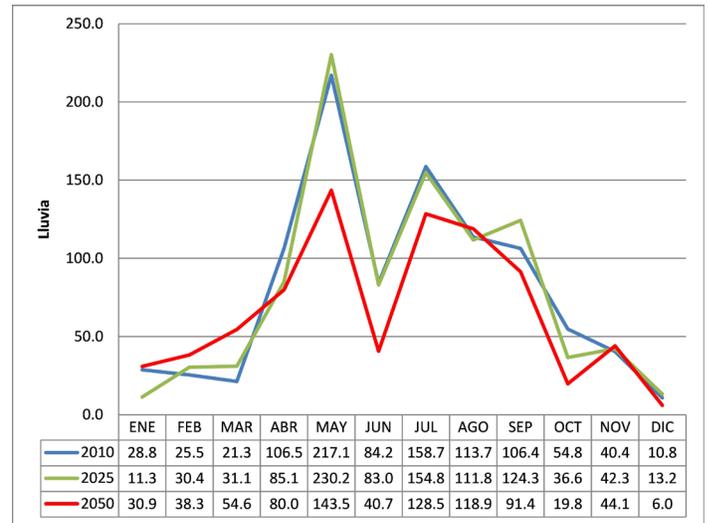
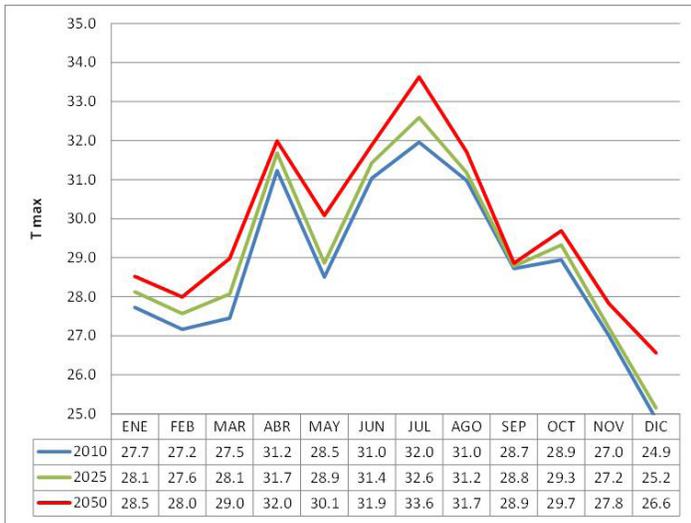
According to McSweeney et al. (2009), mean rainfall has decreased by 5.0 mm per month over each decade since 1960, which corresponds to a reduction of 4.5 percent per decade since 1960. However, Gonzalez Meza (2010) didn't find statistically significant trends among 19 weather stations that measure precipitation, based on a comparison of multi-annual averages of different past periods of time. He concludes that past changes could be arbitrary. It may also be that historical records are too short for any firm conclusions on long-term trends.

No clear trends can be identified for heavy precipitation events (McSweeney et al., 2009). Likewise, according to data presented in Tartaglione et al. (2003), no discernible tendency appears in the number of tropical cyclones making landfall in the Caribbean over the last century. Neither are there any observations on sea-level rise for the Dominican Republic, although an increase of 1.3 mm per year was measured in Panama between 1909 and 1984 (Magrin et al. 2007).

## PROJECTED CLIMATE TRENDS

Simulations of future climate in the Caribbean conducted by the Intergovernmental Panel on Climate Change (IPCC) suggest that temperatures will increase by 1.4° C to 3.2° C, with a median of 2° C by the end of the century (Christensen et al., 2007). National simulations project similar ranges. According to different scenarios used by Planos (2001), temperatures could increase by 0.7° C to 4.2° C by 2100. McSweeney et al. (2009) project that the mean annual temperature will increase by 0.5° C to 2.3° C by the 2060s, and by 1.1° C to 3.6° C by the 2090s. Different projections, summarized in Herrera Moreno and Orrego Ocampo (2011), suggest increases of 0.5° C to 0.7° C by 2020, about 1° C by 2050 and over 2.5° C by 2100.

For rainfall, projections are much less clear. Overall projections predict that various regions of the Caribbean will become drier (Mimura et al., 2007; Centella, 2010). At the national level, different scenarios presented by Planos (2001) project anything from small increases of 4 percent to drastic reductions of 60 percent by 2100. Similarly, McSweeney et al. (2009) present a range of +20% to -55% for the 2090s. In sum, although most models project reductions in rainfall, much uncertainty remains.



Figures 10 and 11. Projections for monthly maximum temperatures and rainfall in the Yaque del Sur watershed for 2010, 2025 and 2050 (originally published in González Meza, 2012)

González Meza (2012) simulated future climate conditions in the Yaque del Sur watershed under IPCC's A1B scenario,<sup>5</sup> based on the MARKSIM<sup>6</sup> model and on climate data for San Juan de la Maguana, a larger town in the middle of the watershed. Projections are available on a monthly basis for maximum and minimum temperatures, solar irradiation, and rainfall. Figures 10 and 11 show the charts for maximum temperatures and rainfall. According to these results, maximum temperatures will increase in every month, but the increase is most pronounced for March, May, July and December. Average annual temperature values rise from 28.8° C in 2010 to 29.2° C in 2025 and 29.8° C in 2050. The pattern for minimum temperatures is comparable. Annual averages increase from 15.7° C in 2010 to 16.1° C in 2025 and 16.8° C in 2050. For rainfall, annual totals are expected to remain stable at around 940 mm per year between 2010 and 2025, but drop to only 766 mm by 2050.<sup>7</sup> Note that while these results are in line with the national and regional projections mentioned earlier, they rely on just one emissions scenario and one climate model, and they only represent one town in the watershed. They should therefore be interpreted with caution.

Estimates presented by Limia and Rosario (2007) for the area of Punta Cana project an increase in sea levels of between 3.8 cm and 25.9 cm for the year 2030. In line with this, McSweeney et al. (2009) project increases of between 18 cm and 56 cm by 2090, relative to 1980–1999 sea levels and based on the application of a regional adjustment to global projections by Meehl et al. (2007). Note, however, that sea levels are also affected by many other factors, including ENSO and volcanic and tectonic crustal motions, which means that current predictions are highly uncertain (Mimura et al., 2007).

Extreme events are more difficult to project. According to Magrin et al. (2007), many regional studies do indicate that extreme events will occur more frequently in the future. CATHALAC (2008) undertook projections for cyclonic activity under the A2 (high emissions) scenario using the PRECIS model, and found that while events may become more intense, their frequency will not vary significantly. However, the methodological foundations for such projections are still weak (Smith et al., 2010). A link between anthropogenic climate change and ENSO has not been established. Changes have been observed in the intensity of El Niño events and the location of the surface temperature abnormality since 1970, but these changes have not been conclusively linked to human-induced global warming (Trenberth and Hoar, 1997; Lee and McPhaden, 2010; McPhaden et al., 2011).

<sup>5</sup> As per the IPCC's 2001 'Special Report on Emissions Scenarios,' the A1 scenario family is based on rapid economic growth but also on the fast introduction of clean technologies. This leads to initially high emissions, but rapid decline in the second half of the 21st Century (ECLAC, 2010).

<sup>6</sup> MARKSIM is a stochastic weather-generator tool used to generate past and future daily weather data for a given area, based on commonly used climate scenarios (Climate Change Agriculture and Food Security, 2012).

<sup>7</sup> To account for small simulation errors, these numbers have been adjusted and do not fully correspond to the total of monthly sums shown in Figure 11.

## STATUS OF CLIMATE AND HAZARD INFORMATION

A relatively complete picture of current and future climate hazards and trends can be obtained from the available data and information. The main driving factors and general characteristics of today's climate are quite well-understood, and the main zones of influence for key hazards have been identified. Projections for future climate are available and appear to be robust, at least for temperatures.

Nevertheless, a few important gaps and deficiencies exist. Data are often patchy and difficult to access. Available climate records have gaps. Different weather stations are managed by different agencies, mainly INDRHI and the National Meteorological Office, and data is not openly shared. As a result, climate hazard data is often inconsistent (Herrera Moreno and Orrego Ocampo, 2011). Return periods and probabilities have not been calculated. Climate projections are also less reliable if climate models rely on observations from only a few weather stations and if data management is not coherent. As a result, projections such as those shown above should be interpreted with caution. Apart from the lack of sufficient and reliable data, risk analysis is also limited by the scarcity of human resources—that is, experts who can conduct such studies.

There is thus a need for more systematic monitoring, processing and accessibility of data, as well as for more complete and up-to-date studies regarding different climate variables. The study on climate change impacts on the area of Bávaro–Punta Cana is an example of the kind of information that should be more broadly available. In addition, capacities in terms of climate science need to be strengthened.

### Key messages: Climate profile

- The Dominican Republic has a tropical climate. It can rain all year, but there are clearly marked rainy and dry seasons in most parts of the country.
- Climate variability is mainly driven by the Intertropical Convergence Zone, Atlantic Ocean oscillations and ENSO, and it manifests in tropical cyclones and storms, heavy rainfall, floods and, to a lesser extent, droughts.
- Observed trends show that average temperatures have increased by about 0.45° C since 1960. Rainfall has decreased by about 4.5 percent per decade, although the significance and consistency of this trend is disputed. No clear trends are available for extreme events.
- Climate scenarios for the national and watershed levels project continued warming of about 1° C between now and 2050, and probably decreasing rainfall. Nationwide, temperatures could increase by up to 4.2° C by the end of the century. Rainfall trends are less clear but tend to be negative, and extreme events remain hard to project.
- Weather and climate data remain patchy and difficult to access, rendering climate information and projections, as well as risk studies, less reliable.

## CLIMATE IMPACTS AND RISKS

Taking into account casualties and GDP losses, the Dominican Republic was the seventh-most-affected country in the world by the impacts of extreme weather events in the period from 1991 to 2010. Over these 20 years, 44 events occurred in the Dominican Republic. These killed over 200 people per year on average and led to annual economic losses of 0.37 percent of GDP (Harmeling, 2011). Floods and tropical cyclones and storms, as well as, to a lesser extent, droughts, have been the major threats.

Table 8 presents records of the human and economic impacts of some of the major climate disasters that occurred in the Dominican Republic over the past five decades. These numbers are incomplete, especially for slow-onset disasters such as droughts, and sometimes conflict with information from other databases. Detailed information about impacts on specific sectors is hard to obtain, except for particular events. Trends cannot be identified with certainty, because record-keeping has improved over time. Nevertheless, the records do reveal the frequency and magnitude of climate impacts in the country. Not only do events with serious impacts occur on a very regular basis and across the country, but several past events can be classified as major disasters, with either several hundred deaths, over a million affected people, or dozens or hundreds of millions of dollars in economic damages.

**TABLE 8. RECORDED IMPACTS OF MAJOR CLIMATE DISASTERS IN THE DOMINICAN REPUBLIC (CENTRE FOR RESEARCH ON THE EPIDEMIOLOGY OF DISASTERS, 2011).**

EVENT	YEAR	KILLED	AFFECTED	ECONOMIC DAMAGES (MILLION USD)
Hurricane Flora	1963	400	-	60
Hurricane Cleo	1964	7	-	1
Hurricane Inez	1966	74	12,942	5
Drought	1968	-	240,000	5
Flood	1979	32	1,000	-
Hurricanes David & Frederick	1979	1,400	1,554,000	150
Flood	1981	20	150,000	-
Flood	1985	12	895	-
Tropical storm	1986	12	2,000	-
Hurricane Emily	1987	3	-	23.7
Flood	1988	-	1,191,150	-
Flood	1991	10	-	-
Flood	1993	12	20,000	-
Hurricane Hortense	1996	24	25,000	-
Hurricane Georges	1998	347	975,595	1,981.5
Flood	2003	1	460	2.1
Coastal flood	2003	9	65,003	42.62
Tropical storm Odette	2003	8	10,000	-
Flood and landslides	2004	688	10,002	-
Hurricane Ivan	2004	4	-	1
Hurricane Jeanne	2004	11	14,009	296
Flood	2007	9	16,000	-
Hurricane Dean	2007	1	1,600	40
Hurricane Noel	2007	129	79,728	77.7
Tropical Storm Olga	2007	33	61,605	45
Hurricane Hanna	2008	1	10,745	-
Flood	2009	2	4,565	44
Flood	2009	5	10,000	8.4
Flash flood	2010	1	25,700	-
Hurricane Tomas	2010	-	12,000	-
Hurricane Irene	2011	1	32,000	-

As table 8 illustrates, hurricanes, storms, floods and landslides—hazards that occur often but not always together—lead to the most recurrent losses and damages to population and the economy. The events in table 5 combined killed over 3,200 people, affected over 4.2 million people and led to almost US\$2.8 billion in economic damages. As mentioned above, these numbers are likely to significantly underreport actual impacts. More detailed accounts are available for individual events.

Two of the worst recent cyclone events include Hurricane Noel and Tropical Storm Olga, which hit the country in quick succession in late 2007. Through both direct and indirect impacts, the two events devastated about 80,000 ha of land, killed over 8,000 head of livestock and led to economic damages of almost US\$200 million (JAD, 2007, in UNDP, 2009). The worst recorded landslide occurred in 2004 in the southwestern village of Jimaní, where several hundred people were killed and 10 percent to 15 percent of the dwellings were destroyed (Herrera Morena and Orrego Ocampo, 2011).

Only one drought is recorded in the EM-DAT database (CRED, 2011), yet droughts are slow-onset events with mostly indirect effects and tend to be less visible in disaster statistics than rapidly unfolding events. Droughts have led to soil degradation and desertification of fragile lands and can cause enormous economic damage. According to Herrera Morena and Orrego Ocampo (2011), the areas most impacted by droughts in the period from 1971 to 2000 were Jimaní, Pedernales, San Juan, Santiago Rodríguez, Barahona, Santiago de los Caballeros, Mao, Azua, San José de Ocoa, Baní and San Cristóbal. Unfortunately, no quantification of impacts is available.

Other relevant climate-related hazards that affect the Dominican Republic include forest fires, which are often associated with drought, and storm surges associated with cold fronts, which lead to coastal erosion and destruction, loss of beaches, and other impacts on people and assets near the coast (Herrera Morena and Orrego Ocampo, 2011).

Whereas the evolution of current hazards is uncertain, gradual climatic changes will pose new challenges to a range of economic and social sectors. In the Dominican Republic's 'Second National Communication to the United Nations Framework Convention on Climate Change (UNFCCC)' (SEMARENA and UNDP, 2009), potential climate change impacts on water, agriculture, health and biodiversity are analysed. For water, the main threats relate to a probable reduction in rainfall, which, in combination with rising temperatures, will increase water scarcity. In addition, sea-level rise can lead to the intrusion of saline water into aquifers. For health, the prevalence of vector-borne diseases such as malaria and dengue could increase thanks to higher temperatures. Climate change will also affect many key crops, due to warmer and drier conditions and possibly shorter crop cycles. For biodiversity, important impacts are expected, but specific risks have not been identified so far.

## PAST CLIMATE IMPACTS IN THE YAQUE DEL SUR WATERSHED

According to the hazard maps shown in the previous section, the Yaque del Sur River basin is heavily exposed to all of the three main climate hazards that regularly affect the Dominican Republic, namely tropical cyclones, floods and droughts. Such events can have devastating consequences. For example, the Yaque del Sur River, in the lower watershed, is thought to have a run-off capacity of about 1,000 m<sup>3</sup>/s, yet the flow increased to almost 10,000 m<sup>3</sup>/s during Hurricane Georges in 1998. According to the Dominican Agribusiness Board (JAD, 2007, in UNDP 2009), Hurricane Noel and Tropical Storm Olga destroyed large areas of crops, including 8,000 ha of avocado plantations and 2,600 ha of plantains. Floods are known to threaten inhabited and cultivated areas, mainly in the lower watershed, especially in the plains and near river bends, as well in places where the river faces obstacles such as bridges and dams.

No systematic information exists on the impacts of climate hazards in the area. In order to partly fill this gap, consultations were conducted with local stakeholders across the watershed as part of the CRM TASP. González Meza et al. (2011) held focus group discussions, based on the CRiSTAL<sup>8</sup> methodology, with five rural communities as well as four irrigation committees in the lower and upper river basin. Irrigation committees are groups of farmers and other stakeholders who manage water use in a given geographic area. While the consultations do not replace quantitative research on climate impacts, they do provide a comprehensive and localized perspective on the importance of different climate hazards and their impacts on lives and livelihoods, as well as on common coping strategies to deal with those impacts.

<sup>8</sup> CRiSTAL stands for Community-Based Risk-Screening Tool – Adaptation and Livelihoods. For more information see [www.iisd.org/cristaltool](http://www.iisd.org/cristaltool).

Table 9 shows which communities and groups were consulted, where in the watershed they were located and which hazards they prioritized in the consultations considering their effects on lives and livelihoods. There is a remarkable coherence across the different groups: Prolonged droughts and storms or cyclones were mentioned as priority hazards in all consultations. As a third hazard, participants from the upper and middle parts of the watershed identified heavy or excessive rain, while the groups in the lower watershed, with the exception of the communities around Barahona, considered the floods resulting from the same heavy rain as a key threat.

**TABLE 9. CONSULTED COMMUNITIES AND GROUPS AND PRIORITIZED HAZARDS (ORIGINALLY PUBLISHED IN GONZÁLEZ MEZA ET AL., 2011).**

COMMUNITY/GROUP	LOCATION IN WATERSHED	(PROLONGED) DROUGHT	HEAVY OR EXCESSIVE RAIN	STORMS OR CYCLONES	FLOODS
Irrigation committee, Padre Las Casas	Middle	X	X	X	
Irrigation committee, YSURA	Lower	X		X	X
Irrigation committees, Yaque del Sur and Tamayo	Lower	X		X	X
Communities of Barahona, Jaquimeyes, El Peñón and La Bombita	Lower	X	X	X	
Community of Los Frios	Upper	X	X	X	

In a next step, focus groups identified the main impacts of these climate hazards. Table 10 summarizes the most important results from all the consultations.

**TABLE 10. CLIMATE IMPACTS IDENTIFIED IN COMMUNITY CONSULTATIONS (ORIGINALLY PUBLISHED IN GONZÁLEZ MEZA ET AL., 2011)**

HAZARD	(PROLONGED) DROUGHTS	HEAVY OR EXCESSIVE RAIN	STORMS OR CYCLONES	FLOODS
Impacts	<ul style="list-style-type: none"> <li>• Loss of crops and fewer cultivated hectares</li> <li>• Loss of livestock</li> <li>• Shortage of water for human consumption and for irrigation</li> <li>• Forest fires</li> <li>• Reduced incomes</li> </ul>	<ul style="list-style-type: none"> <li>• Loss of crops</li> <li>• Plagues and epidemics</li> <li>• Damage to water infrastructure and roads</li> <li>• Sedimentation of canals</li> <li>• Flooding of agricultural areas</li> </ul>	<ul style="list-style-type: none"> <li>• Loss of crops and plants</li> <li>• Loss and erosion of soil cover, landslides</li> <li>• Plagues and epidemics (dengue)</li> <li>• Damage to water infrastructure, roads and homes</li> <li>• Loss in quality of life</li> <li>• Reduced public service</li> <li>• Displacement of families</li> </ul>	<ul style="list-style-type: none"> <li>• Loss of crops</li> <li>• Overflowing of rivers, inundation of crop land</li> <li>• Damage to water infrastructure</li> <li>• Sedimentation of canals</li> </ul>

As the results show, all climate hazards mainly lead to a loss of crops and plants, which then undermines the income basis of farmers in the area. Droughts lead to water shortages that affect both agriculture and direct human consumption. They also lead to forest fires, and to loss of livestock from shortages of water and food. The other hazards mainly relate to an excess of water, which can damage important infrastructure, especially irrigation systems and roads; cause sedimentation of canals; provoke human, animal and plant diseases and pests; and damage soils more permanently, through soil erosion. Such permanent damages also increase the vulnerability of people's livelihoods to future hazards. For example, soils degraded by floods or droughts can retain less water and will therefore suffer even more from repeated lack or excess of water.



Reduced rainfall and higher temperatures, the latter of which lead to increased evaporation rates, are expected to reduce the availability of water in the future. According to modelling results, the total amount of water running through the watershed will decrease from 1,276 million m<sup>3</sup> in 2010<sup>9</sup> to 1,242 million m<sup>3</sup> and 1,163 million m<sup>3</sup> in 2025 and 2050, respectively. These correspond to reductions in water availability of 2.6 percent and 8.8 percent. At the same time, demand will increase, both from continued population growth and because of increased transpiration by plants, which increases the quantity of water required for crops to grow optimally. According to the model, water demand from urban and agricultural use will increase from 1,618 million m<sup>3</sup> in 2010 to 1,634 million m<sup>3</sup> and 1,682 million m<sup>3</sup> in 2025 and 2050, respectively, which correspond to rises of 1 percent and 3.9 percent.

These numbers also highlight the increasing gap between supply and demand. According to the model, the Yaque del Sur watershed is already in deficit, with demand under optimal conditions (if plants had all the water they need to grow optimally) exceeding availability by 343 million m<sup>3</sup>. This deficit could increase to 392 million m<sup>3</sup> by 2025 and 519 million m<sup>3</sup> by 2050 if the assumptions of the model hold.

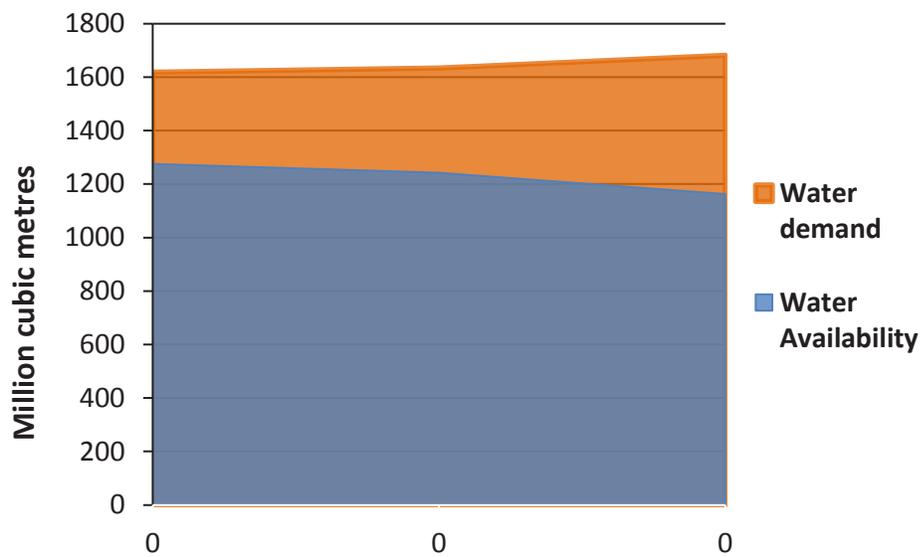


Figure 13. Projected water availability and demand for the Yaque del Sur River basin (Data source: Flores-Lopez, 2012)

Note that the results in figure 13 are highly sensitive to assumptions such as climate projections, population increases (estimated in the model at about 2 percent per year) and others. While temperature increases appear quite certain, the error margins for rainfall are still large. As a result, future water scarcity could be more or less pronounced than the model results suggest.

### Crops

In order to understand the implications of changing temperature and rainfall conditions on some of the key crops grown in the Yaque del Sur watershed, González Meza (2012) applied the Decision Support System for Agrotechnology Transfer model. Ecophysiological models like this one can predict climate change impacts more precisely than other methods, because they take into account soil texture, water demand and use for crops, temperature, and soil nitrogen dynamics, as well as agricultural practices such as crop varieties, planting dates, row spacing, irrigation, fertilization rates and timing. Of the main crops grown in the area, maize, tomatoes and chilies are represented in the model. Note that the results of this study should be interpreted carefully, as they rely on few simulations and just one climate scenario.

<sup>9</sup> Note the large difference in this value compared with the one presented in table 5. The difference is probably due to the definition of the catchment area: Whereas the model results presented here refer strictly to the Yaque del Sur watershed, other results may include the larger area, including other rivers as well as Lake Enriquillo.

González Meza (2012) finds that the gap between expected and potential evapotranspiration of these crops will increase dramatically in the future. First, as indicated by the above results of the application of the WEAP model, rising temperatures and decreasing rainfall reduce the availability of water. At the same time, plants require more water to grow as the evaporation from soils and the transpiration from plants increases. In the absence of optimal irrigation and fertilization, the water deficit accumulated over the entire crop cycle could reach approximately 200 mm for tomatoes, maize and chilies. The simulations also indicate that the water deficit will be more pronounced during certain periods of the crop cycle, especially in the dry period from December to March, when most annual crops are planted and perennial crops are in a critical phase. Crops with longer cycles and higher water demand, such as bananas, plantains and pigeon peas, are generally expected to be more sensitive to the projected changes in climate.

Two other crop models, AEZM and WOFOST, have recently been applied in the Dominican Republic (SEMARENA and UNDP, 2009). In line with the results of González Meza (2012), these models suggest that increasing temperatures, shorter crop cycles and more water scarcity could affect crops significantly, especially in the absence of irrigation. Detailed results for San Juan de la Maguana, which lies in the upper Yaque del Sur basin, are as follows: By 2020, yield reductions for yucca, potatoes, rice and sweet potatoes on the order of 5 percent to 20 percent are expected, depending on the underlying climate scenario. By 2080 some crops, such as rice and sweet potatoes, could become almost impossible to grow, at least during the current crop seasons. For rice, the available period for cultivation could be reduced from over six months to less than four months by 2080.

## VULNERABILITY TO CLIMATE HAZARDS

The current and potential future climate impacts described above are not an inevitable consequence of climate hazards such as hurricanes, heavy rain, floods and droughts, but result from the interaction of these hazards with vulnerable environmental and socio-economic conditions. Vulnerability is in itself a function of sensitivity and adaptive capacity. The population of the Yaque del Sur watershed is highly sensitive to climatic conditions, for a number of reasons. Their livelihoods depend to a large extent on agriculture, which is itself very dependent on the climate, especially because climate affects critical water resources. As the analysis above shows, water is already scarce in the Yaque del Sur area, and is bound to become even scarcer in the future. Rain-fed agriculture is particularly sensitive to rainfall conditions, but even irrigated agriculture will be affected if overall water availability is insufficient. Given that agriculture already uses a very high share of the available hydrological resources, there is little or no room to expand its water use. Some of the main crops of the area, including bananas, plantains and pigeon peas, require a lot of water, so scarcity will affect them directly. Livelihoods are also dependent on infrastructure, including roads to access markets, and these are also susceptible to climate impacts.

Vulnerability also depends on adaptive capacity, which relates to the ability of institutions, systems and individuals to adjust to potential damage, take advantage of opportunities or cope with consequences. Adaptive capacity depends on the development context. With low levels of income and education, the inhabitants of the Yaque del Sur watershed largely lack the capacity to understand climate risk and take the necessary steps to reduce risk. Furthermore, the lack of land ownership by many farmers means they have little interest in investing in sustainable farming or ability to do so, though sustainable farming could contribute to risk reduction.

Adaptive capacity is, however, very context-specific and cannot be understood by looking at aggregated statistics alone. Therefore, the communities and irrigation committees consulted on climate impacts were also asked about how they deal with these impacts today, and whether they think they have sufficient means to reduce climate risks. Indeed, although adaptive capacity remains insufficient, many of the communities consulted by González Meza et al. (2011) can to some extent resort to sustainable coping and adaptation strategies, as table 11 shows.

**TABLE 11. SUSTAINABLE ADAPTATION AND COPING STRATEGIES IDENTIFIED BY CONSULTED COMMUNITIES AND IRRIGATION COMMITTEES (ORIGINALLY PUBLISHED IN GONZÁLEZ MEZA ET AL., 2011)**

HAZARDS	SUSTAINABLE COPING AND ADAPTATION STRATEGIES	
	IRRIGATION COMMITTEES	COMMUNITIES
Droughts	<ul style="list-style-type: none"> <li>• Use efficient irrigation techniques</li> <li>• Change to crops with higher economic value*</li> </ul>	<ul style="list-style-type: none"> <li>• Install drip irrigation systems</li> <li>• Conserve water</li> <li>• Promote perennial crops</li> <li>• Engage in pasture</li> </ul>
Storms or cyclones	<ul style="list-style-type: none"> <li>• Adjust crop cycle (early harvest)</li> <li>• Lop banana and plantain trees (early harvest)</li> </ul>	<ul style="list-style-type: none"> <li>• Build safer homes</li> <li>• Plant trees</li> <li>• Improve disaster-prevention capacity (e.g. through local emergency committees, equipment, etc.)</li> </ul>
Heavy or excessive rain	<ul style="list-style-type: none"> <li>• Install drainage works</li> </ul>	<ul style="list-style-type: none"> <li>• Conduct prevention campaigns against diseases</li> <li>• Conduct emergency mapping and planning</li> <li>• Diversify crops</li> </ul>
Floods	<ul style="list-style-type: none"> <li>• Build protection walls</li> <li>• Adjust crop cycle (early harvest)</li> <li>• Install drainage works</li> </ul>	n/a

\* To be sustainable in regard to climate risk, they should use less water, as well.

Other strategies may help communities recover from or absorb shocks temporarily, but are not necessarily sustainable or desirable in the longer run. For example, in several consultations the renewed cultivation of crops or cleaning up of sedimentation after storms or rains was mentioned. While both can reduce the longer-term negative impact of a recent event, they are reactive and do not in themselves prevent impacts of future events. In other cases, coping strategies even reduce long-term adaptive capacity. For example, some communities are forced to sell animals to buy other food items in times of drought, which reduces their asset base and may render them more vulnerable to future shocks.

Overall, the consulted communities and irrigation committees do have some means to adapt to extreme events, or at least ideas on how to do so, although they may need external support and changes in land tenure to put some of these into practice, especially those involving investments in infrastructure. It is less clear, however, how easily they will be able to cope with the additional stress imposed by a changing climate. While the population may have a long experience in dealing with extreme events, climate change will provoke new situations, such as unprecedented water scarcity and unstable rainfall patterns, which may lie outside the existing coping range. As a result, forward-looking measures such as those proposed in section 6 will be needed.

### CLIMATE THREATS TO DEVELOPMENT OUTCOMES

The combination of high exposure and sensitivity to climate hazards with insufficient adaptive capacity leads to significant and increasing climate risk for agriculture. In the PSD workshop held with members of communities and irrigation committees of the Yaque del Sur watershed (Zamudio et al, 2011), participants were asked what the main current and future impacts on the development goals they proposed for the year 2025 would be (see section 2). The following impacts were seen as the most important:

- Increasing seasonal as well as permanent water scarcity for human use and agriculture, due to increasing demand and possibly decreasing supply.
- Possible reductions in yields of key crops, because of increased water scarcity, higher temperatures and continued soil degradation.
- Inter-annual variation of yields, due to frequent extreme events, especially hurricanes and floods.
- Loss of life during extreme events.
- Increasing occurrence of forest fires due to dry conditions.
- Damage to crucial infrastructure, such as farms, irrigation systems, water storage and access roads due to storms, cyclones and heavy rains.

In addition to the local and immediate impacts on farmers' livelihoods, there are indirect consequences for the society and economy at large:

- Reduction in rural incomes from agriculture, which affects the entire value chain.
- Increased food and water insecurity due to lower crop yields as well as higher food prices.
- Rising malnutrition because of lower crop yields in general.
- Decreasing exports and increasing need for imports of affected crops.

Such impacts put the achievement of several key national and sectoral development objectives at risk:

- Rapidly **reducing rural poverty**, as proposed in the 'National Development Strategy,' is harder, because of lower agricultural incomes, which affect a large proportion of the rural poor.
- Likewise, **reducing inequality** is also more difficult, not least because other economic sectors are probably less climate sensitive.
- **Reducing hunger and increasing food security**, as stipulated in the MDGs, are directly challenged by reduced and less stable food production.
- Social development goals such as **improving education and health** could become more difficult to attain, too, if families dependent on agricultural incomes lack resources to access services. Children may be obliged to work in the field to improve meagre crops rather than going to school. Food insecurity and malnutrition could rise and compromise health objectives such as reducing child mortality.
- Increasing water scarcity will make **extending water access** more difficult and expensive.
- **Preserving environmental resources** can become more difficult in the context of increased scarcity, as unsustainable responses to climate stress may increase deforestation and environmental degradation.
- **Increasing agricultural exports**, as the 'National Development Strategy' proposes, is more difficult in the context of decreasing and more uncertain crop yields.
- **Institutional goals** at different levels, including those stipulated in the 'National Development Strategy,' could also become harder to achieve if communities face social disintegration as a result of increasing resource conflicts and emigration.

These threats are heightened by the relative importance of agriculture in the country's economy and society. Furthermore, since climate hazards will increasingly exceed the coping capacity of communities, they may gradually resort to more unsustainable responses such as agricultural expansion, deforestation and conflicts over resources, which can in turn jeopardize other development goals and increase vulnerability. Risk-management policies and measures are needed at different levels to minimize climate risk.

### Key messages: Climate impacts and risks

- Almost every year cyclones, storms and floods, as well as, to a lesser extent, droughts, claim dozens of lives, affect tens of thousands of people or cause millions of dollars of damages. The Yaque del Sur watershed lies at the intersection of all these hazards.
- Climate change could lead to additional stress. Water scarcity will most probably increase: according to model results, there could be a shortfall of over 500 million m<sup>3</sup> by 2050, and key crops grown in the area, such as tomatoes, maize and chillies, will require more water for optimal growth, or will experience important reductions in their yields. Crops with longer crop cycles are more vulnerable, because temperature rises and precipitation reductions are concentrated in certain months.
- Adaptive capacity is insufficient. The Yaque del Sur watershed is one of the poorest regions of the country. Irrigation committees and communities in the watershed do have strategies to cope with climate risk, but climate variability and change is increasingly overwhelming coping capacity and may make the use of sustainable coping strategies less likely. Sustainable adaptation often requires external support.
- The combination of hazards and vulnerability leads to significant climate risks and can jeopardize the achievement of national and sectoral development goals, including the reduction of rural poverty and inequality and improving food security.

## INSTITUTIONS AND POLICIES FOR CLIMATE RISK MANAGEMENT

This section looks at current institutional and policy arrangements for climate change adaptation and disaster risk reduction as well as key actions, followed by an analysis of current risk management capacity. While the focus is on the national level, the section aims to provide a picture of the enabling environment for the targeted and more local risk management strategies proposed in the next section.

As in most countries, climate risk management is currently addressed from two main angles: disaster risk management and climate change adaptation. Climate change adaptation considerations are also increasingly being mainstreamed into national and sectoral policy documents. The following sections describe the current structures and achievements in these areas.

### DISASTER RISK MANAGEMENT

The National System for Disaster Prevention, Mitigation and Response (SNPMRD) integrates all the rules, institutions and activities relating to disaster risk reduction in the Dominican Republic. Its mission includes disaster risk reduction and prevention, socialization of risk prevention and mitigation, effective disaster response, and rapid and sustainable recovery of affected areas and populations. At the highest level the system is coordinated by the National Council for Disaster Prevention, Mitigation and Response, which is headed by the President of the country and involves a range of ministries and departments. Coordination among different governmental and other institutions on the technical level occurs through the National Emergency Commission. The Commission plans, coordinates and manages all stages of emergency response and recovery, including financial aspects. It has the Emergency Operations Centre as its operative structure for handling the emergency response. The National Emergency Commission is also the focal point for the 'Hyogo Framework of Action.'<sup>10</sup>

Other important elements of the SNPMRD include the Integrated National Information System; the National Fund for Prevention, Mitigation and Disaster Response; and the National Technical Committee, an advisory body to the National Council for Disaster Prevention, Mitigation and Response responsible for coordinating disaster risk reduction activities, establishing regional and local networks and capacity development, and updating the 'National Risk Management Plan' and the 'National Emergency Plan' (Herrera Moreno and Orrego Ocampo, 2011).

At the regional level, the Dominican Republic is an associated state of the regional Coordination Center for the Prevention of Natural Disasters in Central America. The organization belongs to the institutional framework for the Central American Integration System (SICA); brings together the national emergency commissions of the seven Central American countries; promotes and coordinates international cooperation, knowledge exchange, and technical and scientific assistance; and systematizes information around disaster risks. Its main policy instrument is the '2010 Central American Policy on Integrated Disaster Risk Management' (PCGIR) (CEPREDENAC and SICA, 2010), which establishes guidelines, directives and actions, which are to be detailed in more specific plans, such as a five-year regional disaster reduction plan. Among the strategic themes of the policy are risk reduction in public investment; development and social compensation as a means to reduce vulnerability; environment and climate change; territorial management, governability and governance; and disaster management and recovery.

### CLIMATE CHANGE

The State Secretariat for Environment and Natural Resources (SEMARENA), now the Ministry for Environment and Natural Resources, was the main focal point for climate change before the Council for Climate Change and the Clean Development Mechanism (CNCCMDL) was created in 2008. SEMARENA was created in 2000, and its purpose is to design and implement a comprehensive state policy for the conservation and protection of the environment and natural resources. It establishes mechanisms to regulate the sustainable use of natural resources in the country and sets the rules to prevent damage to the environment under the polluter-pays concept (SEMARENA, 2006). The Ministry for Environment and Natural Resources now seems to perform a more technical role

<sup>10</sup> The 'Hyogo Framework for Action' is a 10-year plan adopted by 168 United Nations member states in 2005 to reduce disaster risk. It identifies five priority actions: Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation; identify, assess and monitor disaster risks and enhance early warning; use knowledge, innovation and education to build a culture of safety and resilience at all levels; reduce underlying risk factors; and strengthen disaster preparedness for effective response at all levels (United Nations International Strategy for Disaster Reduction, 2011).

than before, whereas CNCCMDL has taken a more visible leadership role, as it is under the direct supervision of the President of the country. It is officially in charge of promoting new climate change strategies as well as carbon-reduction projects that run under the Clean Development Mechanism (Council for Climate Change and the Clean Development Mechanism, 2011).

CNCCMDL recently presented a draft of the 'Strategic Plan for Climate Change 2011–2030,' which consists of a set of strategic institutional, adaptation and mitigation measures in different sectors (Programa Local de Adaptación al Cambio Climático, 2011). The proposed adaptation measures focus on water resources, agriculture and food security, coastal and marine resources, infrastructure and population settlements, health, biodiversity and forests, energy, and tourism. The 'Strategic Plan for Climate Change 2011–2030' complements the 'Second National Communication,' which, among other things, contains vulnerability studies on water, agriculture, health and other sectors and identifies corresponding adaptation actions (SEMARENA and UNDP, 2009).

SEMARENA also elaborated a 'National Adaptation Plan of Action' (NAPA) in 2008.<sup>11</sup> The NAPA identified, by order of importance, water, agriculture and food security, and coastal and marine systems as priority sectors, because of their high vulnerability and importance in human and economic development. Climate risk management and capacity development are cross-cutting themes (SEMARENA, 2008).

At the regional level, a climate change strategy for Central America and the Dominican Republic has recently been developed under the auspices of SICA (the Dominican Republic is an associated state of SICA) and the Central American Commission for Environment and Development. The strategy summarizes climate information and sectoral vulnerabilities and proposes six strategic areas, of which one is 'vulnerability and adaptation to climate variability and change, and risk management.' Nine strategic objectives, with over 150 measures relating to disaster risk reduction, agriculture and food security, forest ecosystems and biodiversity, water, health, coastal-marine systems, tourism, indigenous people and public infrastructure, are mentioned under this theme. Other strategic areas are mitigation; capacity development; education, awareness-raising, communication and participation; technology transfer; and international negotiations and management (CCAD and SICA, 2010).

## RECOGNITION OF CLIMATE RISK MANAGEMENT IN KEY POLICY DOCUMENTS

Sustainable environmental management and adequate adaptation to climate change compose one of four strategic areas of the Dominican Republic's 'National Development Strategy 2010–2030.' Of the 29 actions mentioned under this strategic area, the water sector receives particular attention. However, the only quantified goal related to adaptation is a commitment to reversing deforestation trends in the coming years. For disaster risk reduction, the establishment of a national risk management system is proposed, without further details (MEPyD, 2010a).

## CLIMATE RISK MANAGEMENT ACTIVITIES

Disaster risk management agencies and programmes have generally been created and pushed forward after major disasters such as hurricanes. The Dominican Republic hosts a wide range of disaster risk projects, many of which involve one or several members of SNPMRD. Important proponents of such initiatives include the Red Cross, Oxfam, UNDP, the Inter-American Development Bank and governmental agencies. Activities cover the full range of disaster risk management, from preventive measures to disaster response and recovery. (Herrera Moreno and Orrego Ocampo, 2011).

UNDP has been a driver of adaptation activities in the country, especially in the elaboration of the national communications to the UNFCCC. In 2009, UNDP started to implement a project aimed at mainstreaming poverty and environmental linkages arising from environmental shocks, such as droughts and floods, into national strategies of poverty reduction, thereby furthering integration. CNCCMDL, in partnership with the United Nations Institute for Training and Research, implemented a pilot project in 2011 in the context of the UNFCCC 'Capacity Development Framework,' aiming to provide training, education and individual capacity development. The 'One UN Training Service Platform on Climate Change' (UN, 2012c) is a collaborative initiative, involving United Nations agencies, which supports Member States, UN agencies and other development partners in designing and implementing country-driven, results-oriented and sustainable learning to address climate change (UN, 2012c). The U.S. Agency for International Development will fund a countrywide vulnerability assessment and implementation of priority recommendations in major

<sup>11</sup> This is not an official NAPA as per the UNFCCC guidelines. The Dominican Republic is not a least developed country and had no obligation to elaborate one.

agricultural regions, by identifying adaptation measures, such as helping small-farm landowners adopt more drought-resistant crop varieties, promoting agroforestry projects on hillsides, employing efficient drip-irrigation systems, and instituting early warning and planning for disasters such as hurricanes, floods and forest fires.

## ASSESSMENT OF CLIMATE RISK MANAGEMENT CAPACITY

Based on the World Resources Institute's 'National Adaptive Capacity Framework' (WRI, 2009), we conducted a short desk-based capacity assessment on climate risk management functions. The framework evaluates capacities based on the availability, systematization and mainstreaming of risk assessments and capacity to conduct them; the existence of explicit risk management priorities and a process to revise these priorities; the existence of coordination processes and bodies; the sound management of information; the identification of risks for priority areas; and the evaluation and implementation of adaptation options.

**Assessment.** A range of assessments on climate vulnerability, impacts and risks have been carried out to date in the Dominican Republic. The 'Second National Communication' (SEMARENA and UNDP, 2009) summarizes evaluations of agriculture, water, health, biodiversity and tourism, for instance. For disaster risks, many post-disaster evaluations have been conducted to assess impacts and damages (see Herrera Moreno and Orrego Ocampo, 2011). More assessments are ongoing or planned. Despite this wealth of information, deficiencies exist in terms of assessment capacity. First, many assessments have been undertaken by external consultants; in-country capacity remains weak. Second, evaluations tend to have a limited perspective, for example by only looking at future climate change and not at current climate stressors, or by basing the analysis and resulting recommendations on only one model or method. Finally, few comprehensive climate risk assessments exist for specific areas, such as the analysis presented in this report. Therefore, future assessments should be more specific and more comprehensive, bringing together different evaluation methods to assess vulnerability and adaptive capacity from different angles, with a view to facilitating concrete interventions that can reduce risk. The capacity of local universities and experts to conduct significant parts of the required research should be strengthened.

**Prioritization.** No explicit prioritization of sectors, areas or actions in terms of climate risk management has taken place in the Dominican Republic. This is a result, first of all, of a lack of a coherent and coordinated approach to managing climate-related risks. Multiple institutional structures exist in disaster risk management and climate change, with no formal interlinkages. In climate change, some sectors have been prioritized implicitly through their inclusion in vulnerability assessments and adaptation plans, yet they are numerous and cover most of the country and economy. The National Adaptation Plan (SEMARENA, 2008) lists 136 actions in various sectors, without prioritizing them. In disaster risk management, not even a long list of actions has been identified. Furthermore, no explicit and ongoing institutional process has been set up to ensure the integration of climate risk management objectives into relevant sectoral public and private policies and actions, or to revisit priorities periodically.

**Coordination.** Within the disaster risk community, decision-making is coordinated by the different bodies of the SNPMRD. For example, the Emergency Operations Centre coordinates emergency responses among different levels and governmental and non-governmental organizations, whereas the National Technical Committee does so for risk management knowledge. On the climate change adaptation side, no equivalent structure exists. The CNCCMDL is concentrated at the national level and not formally related to the Ministry for Environment and Natural Resources, and the two do not have clearly defined competency boundaries. Furthermore, there is no formal coordination between disaster risk management and climate change adaptation. These deficiencies are particularly apparent with respect to data and information. Data is not harmonized, and many institutions keep much of their data hidden (Herrera Moreno and Orrego Ocampo, 2011). Members of one community are often not aware of information available in the other, for example regarding risk studies. In sum, different and relevant aspects of the risk management process are compartmentalized according to function (prevention, response) or time horizon (current risk and future risk), or are duplicated with unclear delimitation of responsibilities.

**Information management.** Related to the deficiencies in coordination outlined above, information management is equally in need of improvement. For example, climate data is collected both by the National Meteorological Office and the National Institute for Hydrological Resources (INDRHI). While information appears to be accessible in emergencies for the Emergency Operations Centre, the data is not available from a centralized database and is hard to access for the public. The same applies for risk information, as institutions are not collaborating efficiently despite the existence of the Integrated National Information System on disaster risks. It is therefore necessary that the resources of this system be improved and that information be harmonized and made accessible to the public.

**Climate risk reduction.** The last element considered in the 'National Adaptive Capacity Framework' is the climate risk reduction function, which captures elements of the previous functions but focuses more precisely on the identification of specific risks to given priorities, the evaluation of adaptation and risk reduction options, and their selection and implementation. As noted above, climate risk assessments have been conducted for several sectors, but a need remains for more comprehensive and specific evaluations. Prioritization of risk management options across regions and sectors is almost non-existent, and adequate inter-institutional mechanisms are not in place for ongoing review and prioritization. Coordination of decision-making is generally weak, especially within the climate change adaptation community and between disaster risk management and adaptation. Information management can be improved, too, as much information is not harmonized and is difficult to access. Apart from better coordination, to adequately reduce climate risks the involved institutions need more resources to effectively conduct their tasks. Even though a National Fund for Prevention, Mitigation and Disaster Response has been established, funds available for disaster risk reduction remain small.

### **Key messages: Institutions and policies for climate risk management**

- The SNPMRD is the Dominican Republic's disaster risk management system. It has the National Emergency Committee, the Emergency Operations Centre and the National Technical Committee as its most important coordination bodies for different aspects of risk management. The National Council on Climate Change and the Clean Development Mechanism shares responsibility for climate change affairs with the State Secretariat for Environment and Natural Resources.
- Climate risks are clearly recognized as a threat to development in the 'National Development Strategy,' and actions are outlined for adaptation to climate change.
- There is no formal coordination between the disaster risk management and climate change structures, and clarity is lacking concerning competencies within the two agencies dealing with climate change.
- The Dominican Republic has a good basis for managing current climate risks, but deficiencies remain regarding vulnerability and risk assessments, prioritization of risks and risk management options, and coordination among agencies, especially between climate change adaptation and disaster risk management. Challenges also exist in terms of information management and the effective implementation of climate risk management actions.

## RECOMMENDATIONS FOR CLIMATE RISK MANAGEMENT

The Dominican Republic has been affected by, on average, at least one disaster event per year. Forty-four disaster events have affected the country over the past 20 years, and over 100 hurricanes and storms hit the country between 1971 and 2008. Climate change could increase the frequency and intensity of extreme events and will gradually exacerbate other stressors such as water scarcity. Combined with the high sensitivity of key economic sectors and the relatively low adaptive capacity to deal with climate change and variability at different levels, but especially among poor, rural communities, such hazards and changes lead to significant risks to economic and social development. The focus region of this study, the Yaque del Sur watershed, is particularly affected, as it lies at the intersection of multiple climate hazards, faces increasing water scarcity, depends largely on agriculture, and is much poorer than the country as a whole.

Yet even in the context of climate change, risks can be reduced if conditions of vulnerability are improved and adaptive capacity is strengthened at national, regional and local levels. This section presents practical recommendations for climate risk management for both the focus area and the national level. The first sub-section looks at concrete actions for the agriculture and water sectors in the Yaque del Sur watershed that were identified in a participatory process with local stakeholders. The second part looks at the need for further research on climate risks and risk management options. The third and final section makes a range of recommendations for policies and programmes at the national level.

### PRIORITY ACTIONS

Most of the following proposals for action to reduce climate risk to the agriculture sector and water resources were identified in a PSD workshop<sup>12</sup> with members of communities and irrigation committees of the Yaque del Sur watershed. In the workshop, participants first created development visions for the upper and lower parts of the watershed for the year 2025 (see section 2). Then, participants were confronted with the information on climate hazards and risks presented in sections 3 and 4 of this report. Based on this, they identified the biggest threats to their own development visions, and then turned to proposing a number of strategies to reduce climate risk. The group working on actions for the upper watershed prioritized improved disaster risk management systems, water efficiency and savings, construction of reservoirs for domestic use and agriculture, implementation of agroforestry systems involving coffee production, and the improvement of capacities in forest fire control techniques such as wind barriers. The group working on solutions for the lower watershed prioritized reforestation programmes for the upper and lower watershed, the selection of adapted crop varieties and use of fertilizer, more efficient water use through better irrigation techniques, and preventive programmes for safe access roads. Further proposed actions are mentioned in the PSD workshop report (Zamudio et al., 2011).

As the final output of the PSD workshop, participants prioritized six climate risk management options and proposed further details for each measure: two for the lower watershed, two for the upper watershed and two for the entire basin. The effects of some of them were further validated in the WEAP model presented in section 4, thus adding a quantitative perspective on the participatory solutions elaborated by irrigation committee members and community representatives. All six priority actions are described in the following paragraphs. A further subsection proposes improvements in climate data collection, monitoring and accessibility.

#### **Replace existing crops with more drought-resilient varieties (lower watershed)**

Water scarcity is a primary concern for communities and producers in the Yaque del Sur watershed. As the crop modelling results in section 4.3 suggest, many crops will not have enough water to grow optimally, even with irrigation systems. Therefore, the PSD workshop group that worked on solutions for the lower watershed proposed replacing existing crops with more drought-resistant ones on a large scale. More specifically, they proposed that 20,000 tareas (1,183 ha) of maize be replaced with sorghum, and 100,000 tareas (5,917 ha) of plantain cultures be replaced by mango production in the areas of Azua, Tamayo and Barahona in the lower watershed. The effect of the proposed changes on water consumption was evaluated with the WEAP model. Due to the high water requirements for plantains, it was expected that this change should decrease water use significantly. Sorghum was also expected to be more efficient than maize under water scarcity. Indeed, the simulation results indicate that crop evapotranspiration will decrease by 16 percent for the entire watershed if the proposed changes are implemented in the lower areas of the river basin. In the three concerned sub-catchment areas, savings amount to 22 percent under current climate conditions, which corresponds to 87.2 million m<sup>3</sup> (Flores-Lopez, 2012). As a result, this option is strongly positive for climate risk reduction.

<sup>12</sup> See introduction for more details.

Workshop participants estimated that these shifts will require capacity development for the farmers, among other things, and estimated the cost at around US\$2 million (over US\$1 million for sorghum, slightly under US\$1 million for mango, and roughly US\$28,000 for capacity development). Funding could come from banks (50 percent), NGOs (40 percent) and farmers (10 percent). Key barriers to this endeavour include land tenure and opposition by farmers.

The latter could indeed be an important barrier, as both economic and cultural reasons could exist for opposing the proposed changes. It may be that mangoes and sorghum yield lower market prices. Also, both maize and plantains are part of the typical diet, so farmers may be reluctant to give up the production of these crops. In addition, the present study has not considered the nutritional value of the crops. In order to conclusively determine the suitability of crop changes, these aspects will have to be incorporated into the analysis. Nevertheless, it should be noted that the proposal itself did come from local members of irrigation committees and communities.

### **Climate-proofing of access roads (lower watershed)**

While paved roads connect the main urban centres of the area with each other and with the rest of the country, many villages depend on unpaved dirt roads, some of which involve river passages. These access roads easily get disconnected during events such as hurricanes and floods. The results of the local consultations presented in section 4 also showed that this is a major concern, not least because roads are vital for market access, and therefore to income generation, as well as for access to goods and services and for emergency operations.

PSD workshop participants from the lower watershed therefore proposed implementation of a climate-proofing programme for access roads, with the main objective being to ensure access during climate extremes such as hurricanes and floods. Such a programme would involve risk mapping, feasibility studies, and acquisition of equipment to reinforce and repair roads. A management committee involving a range of stakeholders should be formed to oversee the works and maintain the equipment. Participants of the workshop estimated the total cost of this programme at around US\$1.3 million. As key barriers, the group identified the lack of political will and the lack of funds.

### **Construction of water reservoirs for domestic use and agriculture (upper watershed)**

Increasing water scarcity is probably the single most important issue affecting lives and livelihoods in the Yaque del Sur watershed. While water is expected to become scarcer throughout the year, seasonal shortfalls could be alleviated through the expansion of water storage capacity. Therefore, the workshop group looking at climate risk management solutions for the upper watershed proposed constructing water reservoirs for both domestic and agricultural use in the communities of Padre las Casas, Bohechío, El Cigual, Los Frios, Las Cañitas, Guayabal and El Limón. This would first involve some analysis of the water situation in each location, looking at both water supply and demand. Then, beneficiaries would be selected (selection criteria were not specified in the workshop). Participatory workshops with the involved communities would be held before the reservoirs were designed and built. Capacity development for users would be also necessary. The total cost is estimated at US\$160,000, of which INDRHI and NGOs would be expected to finance at 25 percent each. Another quarter is to be financed by the municipalities, 15 percent by irrigation committees and 10 percent by communities. Synergies are expected with other NGO projects and plans of irrigation committees. Obtaining permissions from INDRHI is seen as a main obstacle.



*Figure 14. Small water reservoir in the upper Yaque del Sur watershed (Photo: Marius Keller)*

This proposed action was also tested in WEAP. The model was not able to estimate local benefits of additional storage capacity, as this would require a localized analysis of potential uses and their benefits. However, Flores-Lopez (2012) used WEAP to look at the viability of the proposed reservoirs in terms of having sufficient water inflow throughout the year to use their capacity. For modelling purposes, it was assumed that reservoirs would fill up in the night, their content would be used during the day, and they would operate five days a week. Four of the seven reservoirs would have a capacity of 43,000 m<sup>3</sup> each, while the other three would have 22,500 m<sup>3</sup> each.

Under current climate and hydrological conditions, the 97 percent of the annual reservoir capacity could be used. However by 2050, 19 percent of the capacity would be idle due to increasing water scarcity and increasing population (Flores-Lopez, 2012). Nevertheless, it appears that the proposed reservoirs could fulfill their function for the most part, provided they take into account changing water demand and supply in the future. Also, in addition to the capacity development needs mentioned by the workshop participants, it would be necessary to strengthen community water-management arrangements in order to make sure that water storage could be used to the benefit of entire communities, and in coordination with other communities and water users.

### **Implementation of agroforestry systems (upper watershed)**

Deforestation and environmental degradation are key drivers of vulnerability in the region. They undermine agricultural productivity, increase the likelihood of landslides, and, most importantly, they exacerbate climate risks associated with water scarcity or excess, i.e. droughts and floods. Forested water catchment areas produce more reliable and steady water run-off, which is in the interest of water users in the upper as well as in the lower watershed. Deforestation has, however, been largely driven by agricultural expansion. Sustainable solutions must therefore aim at reconciling the private interests of farmers living in water catchment areas and the public interest of the users who depend on the water coming from the same areas.

The workshop group looking at solutions for the upper watershed proposed promoting the implementation of agroforestry systems in the communities of Bohechío, Los Frios, Las Cañitas, Guayabal and Monte Bonito, with a view to protecting catchment areas and reducing soil erosion and flood risk. Agroforestry would involve the cultivation of trees, coffee beans, avocado and mango. In terms of implementation, participants proposed first identifying the locations most suited to agroforestry and then identifying suitable farms. Then, the beneficiaries would have to be identified. Next, plants would be purchased and soils prepared, and then planting could begin. There would need to be a maintenance system. The total costs for doing this were estimated at US\$800,000 for the entire programme. Participants expected that there would be synergies with other projects executed by NGOs and irrigation committees. The lack of funds and political will were seen as the main obstacles.

## **Reforestation of the middle and upper watershed through a payment for ecosystem services scheme**

As the above risk management option illustrates, reforestation is in the interest of water users in both the upper and lower watershed. If communities in the upper watershed protect the forest, they ensure the provision of ecosystems services to users in the lower areas. With that in mind, workshop participants proposed to establishment and expansion of payment for ecosystem services schemes, which rely on revenue from quotas paid by irrigation committees in the lower watershed and fund reforestation activities and the protection of existing forests in the upper basin.

A similar mechanism of compensation has recently been put in place. Called an 'integrated compensation programme for environmental services,' it aims to protect watershed resources, increase, through reforestation incentives, the river basin's capacity to provide water, and improve land use by planting protected species (UNDP, 2011b). However, what is needed is a much bigger fund with wider incentives and specific conditions for reforestation and protection of the upper watershed in order to benefit the overall region.

Specific activities implemented under the scheme would include the improvement of forest conditions in currently protected areas, the reforestation of water catchment areas, and the combination of reforestation with sustainable soil management and permanent cultures, for example through agroforestry schemes as described above. A design study is needed to identify the critical areas and adequate models, propose crop zoning, and determine the amounts to be paid. Institutional arrangements must be established, supported by awareness-raising, consensus-building and the definition of accords. Then, the system can be operationalized. It is expected that the initial study and institutional arrangements will cost about US\$110,000, which would be paid through local funds and international funding. There are many synergies with existing schemes, such as contracts with irrigation committees and other institutions. Barriers include land rights and the potential lack of will from key actors.

## **Increasing irrigation efficiency in the watershed from 20 percent to 45 percent**

As highlighted throughout the report, water scarcity lies at the heart of many climatic risks for the Yaque del Sur watershed. In the Dominican Republic, agriculture accounts for almost 80 percent of water use. As a result, increasing the efficiency of irrigation systems has enormous potential for water conservation and therefore risk reduction. Currently, irrigation efficiency in the Yaque del Sur watershed is estimated at only 20 percent, meaning that 80 percent of the water is lost. According to PSD workshop participants, this figure should be increased to 45 percent by 2025. This could be achieved through capacity development, the introduction of pressurized irrigation systems and drip irrigation, the refurbishment of irrigation canals, and better irrigation practices, among other things. The project should involve a pilot phase with 120 users in Salao and Canoa, according to workshop participants. For small systems, participants proposed connecting them to larger ones by means of new canals. The total cost is expected to top US\$1.6 million, which to the participants hope will be covered by international credits. The workshop participants see synergies with a planned new dam at Monte Grande and the general need to increase the size of the cultivated areas. Environmental impacts could be a potential barrier.

This option was modelled in WEAP (see section 4 for details). The proposed savings of 25 percent would, according to modelling results, amount to about 250 million m<sup>3</sup> of water per year. Given the expected water deficit for the watershed for the year 2050 of about 390 million m<sup>3</sup>, increasing efficiency can make a very large contribution to reducing vulnerability to climate change. Indeed, the WEAP model results suggest that in the areas that use irrigation on a large scale, the water deficit could be reduced by about 50 percent (Flores-Lopez, 2012).

## **Improved climate data monitoring and accessibility**

As noted in the previous section, the collection, monitoring, tracking, processing, analysis and accessibility of climate data could be improved. Data are currently collected by both the National Meteorological Office and INDRHI. Both organizations manage separate networks of weather stations. There is a need to extend the network of weather stations for more accurate information, centralize collection and access to climate information in order to provide coherent and detailed real-time information and forecasts, and provide data inputs for improved studies of climate hazards and risks. More solid climate projections, relying on a variety of emission scenarios and climate models, are also required. These should be calculated for several locations in the Yaque del Sur area and nationwide. Extreme events, their return periods and their frequency should be modelled and calculated.

Access to all forms of climate data is currently limited and needs to be improved at several levels. All information should be easily and freely accessible online. It should also be spread through adequate agencies down to the local level, in order to make sure that farmers and communities can base decisions, such as those related to the timing of planting and harvesting, optimally. Early-warning systems to warn exposed communities of impending floods or other hazards should be established. And climate data should also be accessible to conduct local-level studies on climatic risks and on the design of infrastructure.

### Prioritized climate risk management options

Table 12 summarizes the six prioritized risk management options described above, as well as recommendations regarding climate data and disaster risk management structures, grouped by key themes and indicating expected benefits and the focus regions.

**TABLE 12. PRIORITIZED CLIMATE RISK MANAGEMENT ACTIONS FOR THE YAQUE DEL SUR WATERSHED**

THEME	RISK MANAGEMENT ACTION	EXPECTED BENEFITS	PRIORITY REGION(S)
Water management	Build water reservoirs for domestic use and agriculture	Reduced risk of temporary water shortage	Seven sites in the upper watershed
	Reforest through a payment for ecosystem services scheme	Increased water retention; reduced drought, flood and landslide risks	Reforestation in upper watershed; scheme covers entire basin
	Increase irrigation efficiency by 25%	Reduced water demand and risk of scarcity	Irrigated areas, mainly in lower watershed
Crops and agricultural practices	Select climate-resilient varieties, i.e. switch from maize and plantains to sorghum and mangoes	Reduced water demand by crops and therefore risk of scarcity	Lower watershed: Azua, Tamayo and Barahona
	Implement agroforestry systems	Increased water retention; reduced drought, flood and landslide risk	Five communities in the upper watershed
Infrastructure	Conduct a climate-proofing programme for access roads	Better disaster preparedness; reduced risk of losing market access during extreme events	Lower watershed
Climate data	Improve monitoring, processing and accessibility of climate data	More accurate information for forecasts, early-warning systems, projections, risk studies and design	Entire watershed

While these strategies can be promoted and implemented individually, they can also constitute the basis of a comprehensive climate risk management programme for the entire Yaque del Sur watershed and inspire similar programmes for other regions and the country as a whole. Such programmes will require more explicit capacity development and governance components. Section 6.3 provides more details on these aspects and outlines the components of a national climate risk management programme.

### GOVERNANCE

The priority actions and research needs require adequate institutions, policies and programmes at the different scales to enable and facilitate their implementation. The recommendations stemming from the analysis presented in this report are summarized under three themes: Mainstreaming of climate risk into key public policy documents, coordination among climate risk management institutions and capacity development. A final paragraph proposes the establishment of a national programme to promote a coherent and holistic approach to climate risk management.

Climate change adaptation is prominently recognized in the Dominican Republic's 'National Development Strategy 2010–2030,' as it represents, in combination with sustainable environmental management, one of four strategic areas, and it is substantiated with 29 proposed actions. Surprisingly, however, disaster risk reduction is not mentioned in the strategy, even though it is probably fair to say that, at least over the next 20 years, climate risk related to the kinds of extreme events the country is currently experiencing will

account for a very large share of all climatic risks. These risks should be addressed holistically, and addressing current disaster risks is more urgent and provides a good entry point for larger risk reduction, as respective investments can pay off in the short term. In addition, climate risk management should not be seen as a separate objective from achieving poverty reduction, economic growth and other goals, but as an integral part of any strategy to achieve larger development objectives.

No specific government strategies for the water and agriculture sectors were found in this study; however, it is crucial that climate risk reduction be mainstreamed into the planning and decision-making of the key government institutions, including INDRHI and the Ministry for Agriculture, responsible for these sectors. Apart from integrating climate risk into key documents, this will require institutional structures and processes that allow for establishment of formal connections between climate change and disaster risk agencies and other governmental agencies and ministries. And while mainstreaming should be demonstrated at the national level, it will have to be replicated at regional and local levels; for example by integrating climate change concerns into the work of regional and local disaster risk management units and by considering climate risk in local land-use and development plans.

The capacity assessment in the previous section has brought to light significant deficiencies regarding the coordination of climate risk management policies and activities across institutions. First, despite the existence of the Integrated National Information System on disaster risk management, little information on climate hazards and risks is publicly accessible. Key institutions are reluctant to share data. The Emergency Operations Centre appears to have access to relevant information for early warning, but other agencies seem to lack access to information, which means there is a risk of poor decision-making. As a result, a big push for centralized and open access to climate, vulnerability and risk data and analysis is needed.

Another crucial area is integration and improved coordination among different bodies involved in climate risk management, especially within and between the climate change adaptation and the disaster risk management branches. No clear delimitation exists between CNCCMDL and the Ministry for Environment and Natural Resources, two bodies involved in climate change adaptation, and between these two and SNPMRD, even though most member agencies (mostly government ministries) of CNCCMDL are also members of SNPMRD. These bodies need to simplify structures, clarify responsibilities and facilitate integrated decision-making. Ideally, existing incomplete structures would be replaced by a climate risk management coordination mechanism that brings together all relevant ministries and agencies and allows for the establishment of sector-specific subgroups in order to work on concrete solutions. As noted above, this integration needs to be replicated at lower levels of government.

As for the risk analysis itself, CRM TASP has contributed to building capacity within and outside the government and to analysing and mainstreaming climate-related risks in water and agriculture into local, regional, and national plans, strategies and actions. Yet capacity development needs to go further. Relevant agencies remain understaffed and underfinanced. Experts are hard to come by, even at the national level, which renders the necessary follow-up to the present analysis more difficult. Therefore, building the necessary capacity among key agencies and their staff, including in climate monitoring and analysis, risk assessment, coordination and implementation, should be a priority. Along with improved coordination, better funding and expertise will also increase the political clout of climate risk management agencies to ensure the issue receives adequate attention at the highest political levels.

## **Towards a comprehensive climate risk management programme**

This report has shown the need both to step up efforts to manage climate risk and to coordinate better among different institutions, policies and actions in order to manage risk effectively and efficiently. We therefore recommend that a comprehensive climate risk management programme be established that integrates the above recommendations through the following key elements:

- Integration of disaster risk management and climate change adaptation approaches with each other and into sectoral and national development planning, with a view to delivering comprehensive and coherent solutions in terms of actions, policies and research. This will require the replacement of current institutional structures with simplified, overarching protocols and mechanisms that allow for effective coordination, prioritization and implementation of policies and actions.
- Sector- and region-specific risk assessments and management programmes along the lines of the analysis and recommendations made in this report for the Yaque del Sur watershed but tailored to the respective needs of vulnerable areas and sectors. These programmes should be coordinated and connected with the many existing activities in disaster risk reduction and climate change adaptation to avoid duplication and promote effective intervention.

- Improved data collection and information management, including the provision of free access to a centralized system of climate data and risk information.
- Capacity development for key institutions involved in climate risk management, including on climate data collection, monitoring and analysis, risk assessments, and policy and programme implementation. In particular, the nodal agencies responsible for coordinating risk management need more and better-trained staff.

## FURTHER RESEARCH

The comprehensive climate risk assessment for the water and agriculture sectors in the Yaque del Sur watershed presented in this report complements an already wide knowledge base on the impacts of and vulnerability to climate change and variability. However, as noted in the capacity assessment in the previous section, a number of gaps remain, of which this report has only managed to address some. First, more comprehensive assessments of the nature presented in this report are needed for other sectors and areas. For instance, the innovative combination of methods used in this study could be applied in similar ways to other vulnerable watersheds. In the process of choosing the focus area for this report, the watersheds of Yuna and Yaque del Norte were discussed as alternatives, for example. Area- or sector-specific assessments that bring together different evaluation methods to assess vulnerability and adaptive capacity from different angles provide a powerful basis for decision-making and allow for the identification of concrete interventions to reduce risk, such as those proposed above. This approach could also be used for other important and vulnerable sectors, such as tourism, fisheries, biodiversity and health.

Second, the present analysis could be extended in different ways, for example by looking at other crops, at quantitative impacts of climate hazards, their return periods and factors of vulnerability, or by extending the risk analysis to an economic assessment of the indirect effects on the agricultural sector. It would also be interesting to assess the costs and benefits of proposed climate risk management actions economically, since this would allow assessment of the trade-offs between risk management options and the status quo. For example, the crop changes proposed above have been shown to be beneficial in terms of reducing sensitivity to climate-related water scarcity, yet their economic viability has not been considered. Finally, it will be important to involve national experts in any further research, with a view to building up the currently weak in-country capacity. Again, CRM TASP has made some important contributions in this regard, but the project implementation has also shown the need to strengthen national research capacity further.

### Key messages: Recommendations for climate risk management

- To reduce climate risks related to the water and agriculture sectors in the Yaque del Sur watershed, efforts are necessary to improve water and crop management, infrastructure and climate data.
- Items prioritized as climate risk management actions were a participatory process, the extension of water reservoirs for domestic use and agriculture, reforestation programmes through a payment for ecosystem services scheme, increased irrigation efficiency, a shift to crops with less water demand, the implementation of agroforestry systems and a preventive programme to secure road access during climate extremes.
- At the policy level, climate risk should be mainstreamed into key national and sectoral policies and programmes, coordination mechanisms among relevant government agencies should be improved, collection and sharing of information should be strengthened and facilitated, and governmental capacities should be strengthened.
- A comprehensive climate risk management programme to implement these recommendations holistically should be established.
- Further research could apply a similar combination of methods used in this study to other watersheds inside and outside of the Dominican Republic, and the present study could be extended to include other crops, more quantitative analysis, and economic assessments on both risks and risk management strategies. Involving national experts in these efforts is crucial.

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