Climate Change Management

Walter Leal Filho
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# Climate Change and Health

## Improving Resilience and Reducing Risks

Springer

# Climate Change Management

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# Climate Change and Health

## Improving Resilience and Reducing Risks

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# Chapter 14
# Climate Change and Health Vulnerability in Bolivian Chaco Ecosystems

**Marilyn Aparicio-Effen, Ivar Arana, James Aparicio, Cinthya Ramallo, Nelson Bernal, Mauricio Ocampo, and G.J. Nagy**

**Abstract** Climate change and variability is impacting health, across different spatial scales, ecosystems, and water supply and quality. In Bolivia climate change is operating in a framework of poverty and inequality. This chapter focuses on the Bolivian Chaco ecosystems water availability and indigenous health. An ecohealth research was launched to evaluate rural communities and their vulnerability and impacts to current and future climate conditions. The participatory-based approach incorporates community and indigenous organizations, local and national health, and meteorological services. Main observed impacts at Chaco are water stress and warming affecting watersheds, ecosystems and health. Water-borne diseases (WBD) and diarrheal diseases (DD) affected most children evaluated. An average decrease in rainfall of 5–12 %, up to 25 % in winter, especially at the middle and low watershed, is observed. Future increases in temperature (+1–2 °C for 2030–2050), modified rainy patterns and reduced water availability are expected. The both observed and expected warming and less rainfall are correlated with diarrheal vulnerability ($VCC_{DD}$) and the number of DD cases at rural and indigenous communities. Thus, increasing trends of WBD and DD are likely for 2030–2050. This experience was useful to design Chaco region climate change

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policies and indigenous health adaptation strategies focused on WBD/DD. These included: raising awareness about water and health climate vulnerability and impacts, increasing investments for water sources protection, establishing systems to compensate and protect watersheds and water springs, capacity building, WBD/DD prevention actions, and clean technologies for economic activities.

**Keywords** Climate inequality • Climate scenarios • Ecohealth • Indigenous health • Water availability and quality • Waterborne and diarrheal diseases

## Introduction

> Human health has so far been neglected in public discussions on climate change, as debate has generally focused on the environment and the economic effects of reducing emissions. If climate change goes on unchecked we will see many deaths—we are seeing many deaths already—and you can imagine the human population could possibly go extinct if you take the effects of climate change to their extreme logical conclusion (Berry 2007).

### *Climate Change and Human Health*

> WHO assessment takes into account a subset of the possible health impacts, and assumes continued economic growth and health progress. Even under these conditions, it concludes that climate change is expected to cause approximately 250,000 additional deaths per year between 2030 and 2050. Results indicate that the burden of disease from climate change in the future will continue to fall mainly on children in developing countries, but that other population groups will be increasingly affected (Hales et al. 2014).

There is emerging evidence of climate change effects on human health such as altered distribution of some infectious disease vectors (Smith et al. 2014, Fig. 14.1).

A WHO report estimates future global burden of disease as a result of climate change. For example, it estimates a 10 % increase in diarrheal disease than without climate change in 2030 (Shuman 2010). Increases in the occurrence or severity of extreme weather events could increase the risk of flooding and landslides (see Nagy et al. 2015). Decadal variability and changes in extremes have been affecting large sectors of population, especially those more vulnerable and exposed to climate hazards (Magrin et al. 2014).

Climate change will result in increased incidence of communicable diseases including vector-borne diseases, because their incidence is dependent on climate and water availability. In this sense, climate change extends the geographic and altitudinal incidence of Malaria, Dengue fever and other climate sensitive diseases. Climate change will also affect other sectors which are pillars of health: agriculture, food security, water resources and ecosystems, and contribute to pollution of environmental systems (Aparicio et al. 2007).

Counties are threatened by climate change with direct and indirect health implications for the achievement of countries and health-related development

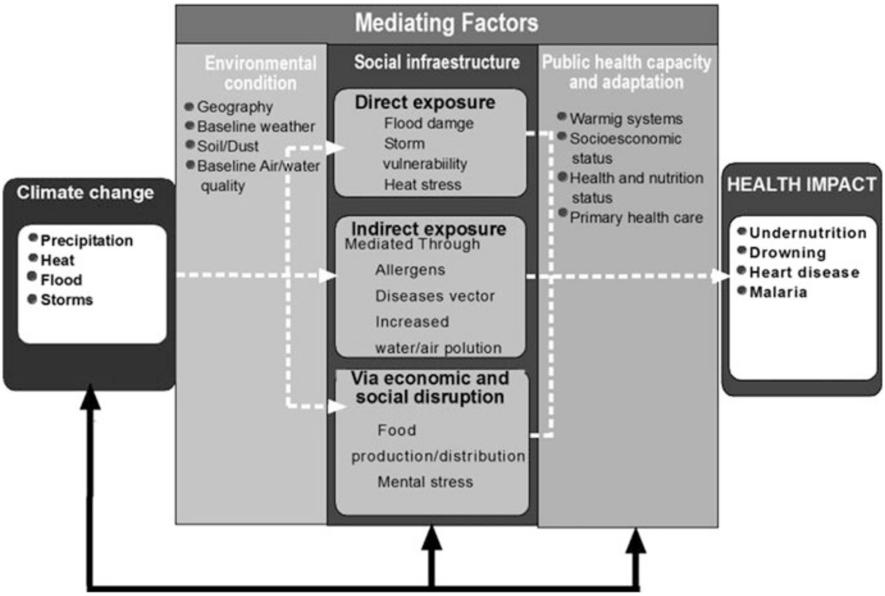


**Fig. 14.1** Conceptual diagram showing three primary exposure pathways by which climate change affects health: Source: IPCC (2014a, b)

goals, including health equity. Many factors operate in a framework of inequality, compounded by failures in urban and rural planning, illegal settlements, constraints on basic services and pollution of environmental systems (Aparicio 2010).

## *Water Borne Transmissible Diseases and Diarrheas*

> Climate change may bring some localized positive effects in health, but, the overall health effects of climate change are likely to be severely negative (WHO 2010).

Diarrheal disease is one of the most important global health problems. The near-term impacts, like damage or pollution of infrastructures as result of extreme events and disasters, or chronic effects such as water resource depletion by climate change effects, are reducing the water quality and overall availability of water. The safety and accessibility of drinking-water are major concerns worldwide, because improving access to safe drinking-water can result in improvements to health, particularly for children under 5 years old (C.U.F.Y.O). The epidemiological profile in developing countries is marked by diseases of current socio-economic inequalities. The access to safe drinking-water and sanitation for vulnerable groups, like indigenous and rural population, is still low (Aparicio 2010; PAHO 2011).

In Latin America 93 % have access to improved drinking water sources and 80 % have access to improved sanitation. However, these statistics do not reflect the quality of water or the disparities in countries, gender, income, and race which affect access to water sources and sanitation. Solid Waste Management and Wastewater and Excreta are also important to water quality and human health, impacting the prevalence of WBD (PAHO 2011).

In Andean countries, glacial retreat by global warming is reducing the quality and availability of drinking-water, and also threatens hydroelectricity supply (Nagy et al. 2006; Aparicio 2010). In Bolivia, 80 % of glaciers are retreating (Francou and Vincent 2007).

The risk factors for diarrheas outbreaks after disasters are associated with population displacement, the availability of safe water and sanitation facilities, the degree of crowding, the underlying health status of the population, and the availability of healthcare services, all of which interact within the context of the local disease ecology to influence the risk for communicable diseases and death in the affected population (Watson et al. 2007).

Increased precipitation will increase the risk of flooding and human exposure to pathogens, as contaminants are spread by floodwaters, producing WBD, the most common being a variety of diarrheal illnesses. Water scarcity is associated with diarrhea too. A study in 18 Pacific islands, considering average weather conditions over a 10-year period, found that all-cause diarrhea increased with decreasing water availability (Singh et al. 2001).

Health risks may arise from consumption of water contaminated with infectious agents, most of them sensitive to climate change. Since the early twentieth century, new infectious agents have emerged. Also, other pre-existing agents who were considered controlled re-emerged (Londoño et al. 2011).

Diarrheal disease transmission is known to be affected by temperature. Major viral agents such as rotavirus typically peak in the winter seasons in temperate countries. In tropical settings, rotavirus occurs year round and seasonality may be masked by high background levels (Parashar et al. 2003). Rotavirus infection is the most common cause of diarrhea in C.U.F.Y.O worldwide. While the incidence of rotavirus infection in developed and developing countries is similar, 80 % of deaths occur in developing countries (PAHO 2014).

Rates of diarrhea have been associated with high temperatures (Kolstad and Johansson 2011). Mostly, however, the specific causes of the diarrheal illness are neither known, nor are the mechanisms for the association with temperature. Exceptions include Salmonlla and Campylobacter, among the most common zoonotic food-and water-borne bacteria (Smith et al. 2014).

The climate change and its variability is affecting the water availability and quality in many parts of the world, resulting in a complex combination of climate and non-climate factors or health determinants (PAHO/WHO 2011), that are impacting human health.

Traditionally, the current evidence of the impact of climate on the epidemiology of WBD is considered under three headings; the impact of: (1) heavy rainfall events, (2) flooding and (3) increased temperature (Hunter 2003). However, few specialized literature related with dry lands (as Chaco regions), droughts and chronic effects of climate change on WBD is available. For instance, a Brazilian national assessment showed the North-East region as the most vulnerable to climate change impacts on health, due to poor social indicators, high level of endemic infectious diseases and periodic droughts that affect this semi-arid region (Confalonieri and Marinho 2005).

The aim of this article was to review and update research of the Climate Change and Environmental Health Unit (UCCLIMAS), Universidad Mayor de San Andres (UMSA), La Paz (see Aparicio-Effen et al. 2015) on waterborne transmissible diseases (WBD) in Chaco ecosystems. The research was based on an ecohealth approach focused on water availability and quality, head watershed ecosystem assessment, socio-economic status of populations and vulnerability, associated with environmental health and change, climate variability, and climate scenarios.

### *Indigenous Health and Climate Inequality*

> Indigenous peoples remain on the margins of society: they are poorer, less educated, die at a younger age, are more likely to commit suicide and, in general, have poorer health than the rest of the population (IWGIA 2006).

Even though the indigenous populations represent an important group of cultures, religions, pharmacopoeia, traditions, languages and histories, they are marginalized worldwide in terms of access to education, justice and health. This is exemplified by the high incidence of diabetes among aboriginal Australian population (Hanley 2007), of suicide among Canadian Inuit youth (Health Canada 2013), and of infant mortality among indigenous children in Panama (PAHO 2002). This situation may be exacerbated by climate change, being a highly vulnerable group to its impacts, compromising their means of subsistence and habitat.

## Study Area: The Bolivian Chaco Region “Chaco Boliviano”

### *The Pilcomayo River Basin and Ecosystems*

The Pilcomayo River Basin (210,000 km$^2$ in Bolivia, Paraguay and Argentina, Báez et al. 2014) is located in the Chaco region (15–31° South) shared by four countries: Argentina, Paraguay, Bolivia and Brazil. The “Gran Chaco” is dominated by plains with few hills and small mountains, with sandy and clayey areas. The vegetation is characterized by low deciduous forests, thorn scrub succulent columnar 5–15 m tall, with distinct vegetation according to site geology. The Project study area includes Camiri, Machareti, Villamontes, Yacuiba and Carapari


**Fig. 14.2** Chaco regions: location of case studies

municipalities at "Gran Chaco" and "Chaco Serrano" with altitudinal ranges between 200 and 600 m (Fig. 14.2).

Human activities in the region are livestock, oil drilling, logging for firewood and charcoal, as well as an intensive and subsistence agriculture according to tenure of the land (Erickson 1988; Killeen et al. 1993; Ibisch et al. 2003; Bush et al. 2010). At present, this region accounts with economic resources from taxes from the natural gas industry but due to their low adaptation capacities they do not invest in the implementation of climate adaptation measures.

## *Climatic Setting*

The Chaco climate is influenced by two high pressure systems: sub-tropical South Atlantic Anticyclone which contributes with warm and wet air and erratic and

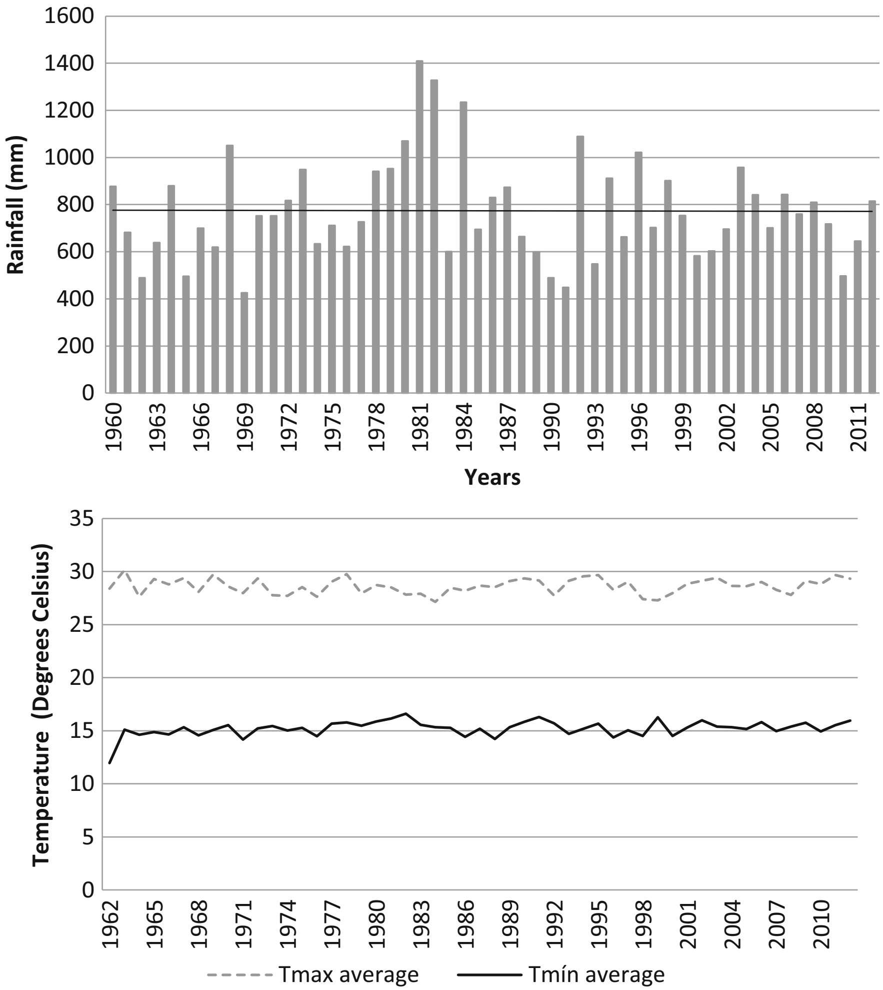


**Fig. 14.3** Time-series (1960–2012) of rainfall (mm, above), and temperatures minimum and maximum temperature average (°C, below) at Northern Chaco (Camiri weather station). Elaborated by the authors from SENAMHI database 2015

concentrated rainfall, and Sub-tropical Pacific South anti-cyclone which brings secondary air mass after crossing the Andes "cordillera".

The region is characterized by high temperature and low and irregular precipitation distribution throughout the year. Rainfall distribution is erratic with long dry periods and frequent droughts. Summer time (December-March) is rainy totalizing more than 60 % of annual precipitation. In northern Chaco (Camiri) the annual precipitation is around 800 mm and in the South (Yacuiba) it is around 1200 mm (Fig. 14.3).

The temperature average is 22 °C (−1 to 44 °C) with normally erratic behavior precipitation concentrated in January and February. Camiri weather station (810 m. a.s.l), region, showed increases of 4.1 °C minimum temperature and 1 °C maximum temperature from 1960 to 2012 (Fig. 14.3) whereas precipitation decreased by 8.1 %.

Seasonal rainfall distribution shows long dry periods (Fig. 14.4) coincident with high temperatures and water stress (Fig. 14.5). Subsequent results are desertification trends due to fast soil humidity lost. These changes will enhance hydrological stress for rain-fed water supply, and extreme weather events, with negative effects in water stock systems in rural and indigenous communities which depend on livestock, being highly vulnerable to recurrent strong droughts which cause health human effects and the loss of cattle and crop production. Less rain could produce ecosystem deterioration with loss of water availability in the low watershed. In Chaco ecosystems, long dry periods, warming and decreasing or stable rainfall, would increase desertification with loss of biodiversity and reduction of water availability.

Because of climate change some regions will experience an increase in rainfall and flood risk, while regions that are prone to droughts may experience more extreme droughts (SDWF 2015).

El Niño Southern Oscillation (ENSO) warm phase "El Niño" is associated with rainfall decrease and temperature increase, especially during austral spring months (October-December). During El Niño 1997 event a severe drought and warming occurred from July to September. The Multivariate Normalized Index shows that ENSO 1997–1998 was the strongest in the past century (Fig. 14.6) (see Nagy et al. 2015).

## *Ethnics Groups, Cultural and Socioeconomic Characteristics*

> Bolivia is going through a major process of decolonization reestablishing the country into a new political scenario which has generated a set of changes and transformations in indigenous and native peoples' role. This process has resulted in new State Constitution (2009), and new model of state and society, surpassing the old monoculture state that favored only one language, one religion and a state structure which excluded the large multicultural majority.

The Weenhayek or Weenhayeey (plural) are found in Bolivia, Argentina and Paraguay. In Bolivia, they are located bordering Pilcomayo River and move from Villamontes town to Yacuiba in Chaco. They are fishermen, but also practice hunting, gathering of natural fruits, animal husbandry and subsistence farming.

The Weenhayek keep some semi-nomade habits, with internal migration (in Bolivia) and external to Argentina and Paraguay, where they tend to form families and get triple nationality. Some of them live in Tuntey neighborhood at Villamontes city. However, they follow a migration pattern City–Country and vice-versa in search of natural products, forest and river, improving their income, and

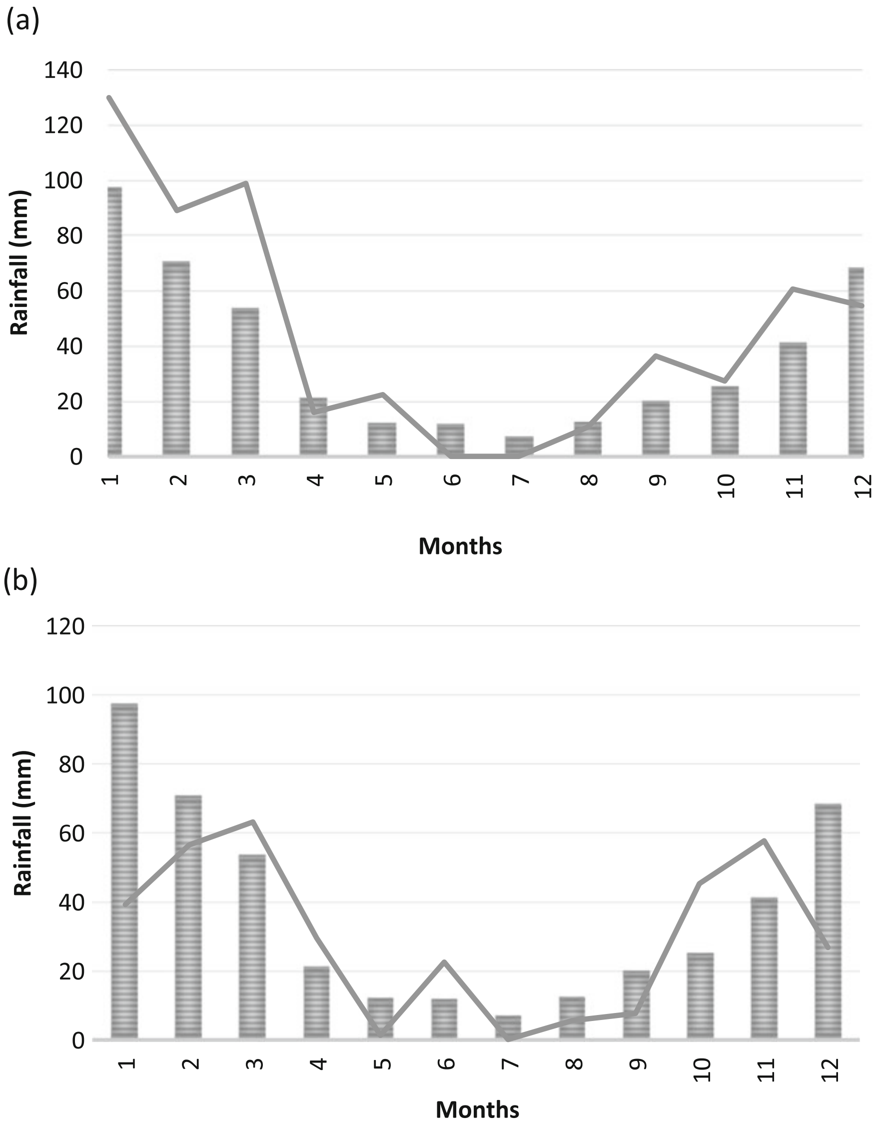


**Fig. 14.4** Rainfall distribution (*Gray bar charts*: rainfall average). El Niño1997-98 (*Gray line*). (**a**) 1997 and (**b**) 1998

accessing to education and/or employment, which also explain the external migration.

In their culture the egalitarianism, reciprocity, freedom of movement, and a strong rejection of authority and domination prevails. "*They maintain the idea that "everything that a person needs, it's been already created by nature"* and that the

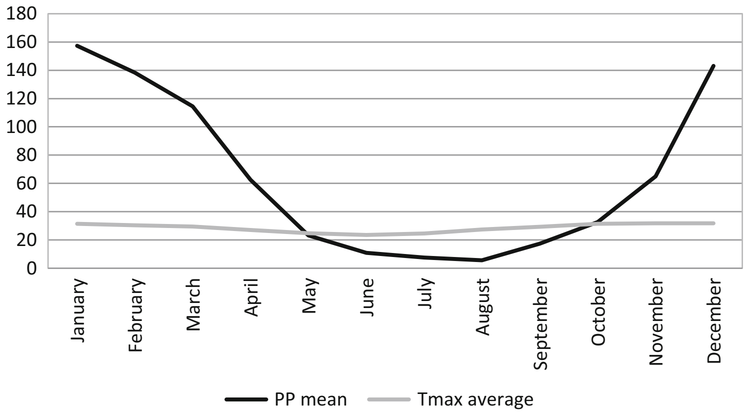


**Fig. 14.5** Chaco seasonal rainfall (mm) (*black line*) and maximum temperature (°C) *(gray line*) distribution. Elaborated by the authors from SENAMHI database 2015

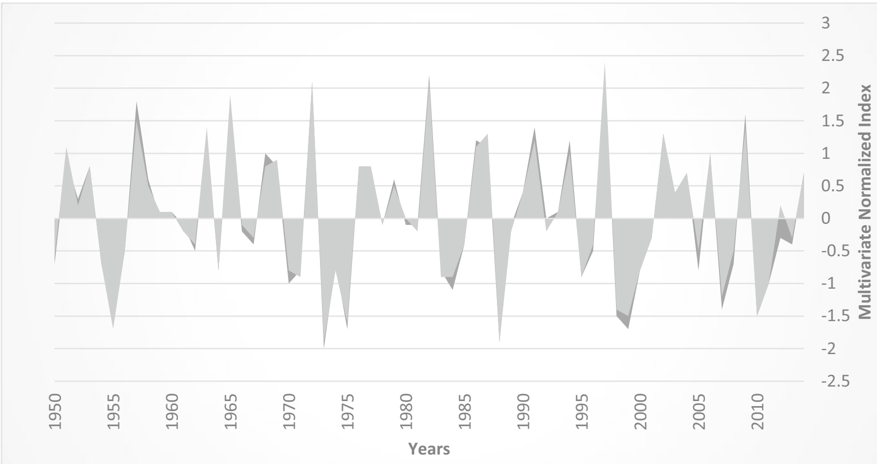


**Fig. 14.6** Time-series of multivariate normalized index. Source: NOAA (2015)

*spirits of the dead remain for a while on earth and can mobilize other relatives, so they usually leave their homes after a death*" (Cortez 2005).

## Approaches and Methods

### *Ecohealth Approach*

Advancing the field of ecosystem approaches to human health (ecohealth) has been a major contribution of International Development Research Center of Canada (IDRC) in its efforts to improve the health of communities in the poorest regions of the world (Charon 2012).

Ecosystems are showing signs of being unable to provide the services people require of them (Hassan et al. 2005). The global environmental changes, their impacts and overexploitation of the earth's resources are showing socio-economic interactions, and have all contributed to our awareness of the interdependency of the human societies and the well-being of our planet.

"Ecohealth is a field of research, education and practice that integrates scientific evidence, professional expertise and community experience with a view to improving the health of humans, animals and ecosystems". "A focus on health—across humans, animals and other species—offers new opportunities to harness synergies across disparate efforts to address climate change" (Borbor-Cordova et al. 2008; EcoHealth 2014).

The ecohealth approach impulse transdisciplinary frameworks of health-research and partnership projects with stakeholders and affected communities. The ultimate objective of ecohealth research and practice is to develop environmentally sustainable, community-based interventions to improve the health of affected communities (Charon 2012).

A Chaco ecohealth research initiative funded by IDRC was launched to evaluate the climate change and variability health vulnerability for WBD considering climate, hydrological, ecosystem, and health characteristics of 17 urban, peri-urban and rural communities, focusing in Weenhayek ethnic group. A participatory-based approach was followed which incorporates community and indigenous organizations, local and national health system, and meteorological services.

Thus, a methodological approach to assessing human health vulnerability to climate change and variability (VCC) arises from the vulnerability criteria of the IPCC (2007) as vulnerability factors: exposure, sensitivity, the character and magnitude of climate change, and adaptive capacity:

$$V : f(Exp; Sensib; CMC; C_{R-A})$$

Where:

| | |
|---|---|
| V | Climate change vulnerability |
| Exp | Exposure to climate change. |
| Sensib | Sensitivity. |
| CMC | Character, magnitude of climate change |
| $C_{R-A}$ | Adaptive capacity |

Herein, ecohealth approach incorporates disciplines (evolving transdiscipline) as vulnerability dimension for diseases research. Each vulnerability dimension: epidemiology, sociology, hydrology, biology, entomology, economics, or others are studied for a particular study object (diarrhea: $VCC_{DD}$ ) including a selected number of variables, which are analyzed considering complex and systemic thinking (Morin 2007) and by comprehensive evaluation (Lessem and Schieffer 2010). So the $VCC_{DD}$ is the result of the interaction of vulnerability factors on vulnerability dimensions, with consequent variations in time and space, and magnitude.

The Vulnerability (VCC) (Fig. 14.7) framework is "a process in motion", so that the evaluation of climate system has to consider past, current and future climate, where the character and magnitude of change between past and current climate (Delta 1) and the current and future climate (Delta 2) is estimated according to emission scenarios and different models.

This approach refers to an object of study (diarrheas), related to a discipline, science or sector, where their exposure, sensitivity and adaptive capacity is analyzed as well as the climatic and non-climatic pressures that influence the aforementioned object. It unfolds in a spatial field of analysis, which indicates the geographical change between locations of the region of the human system whose

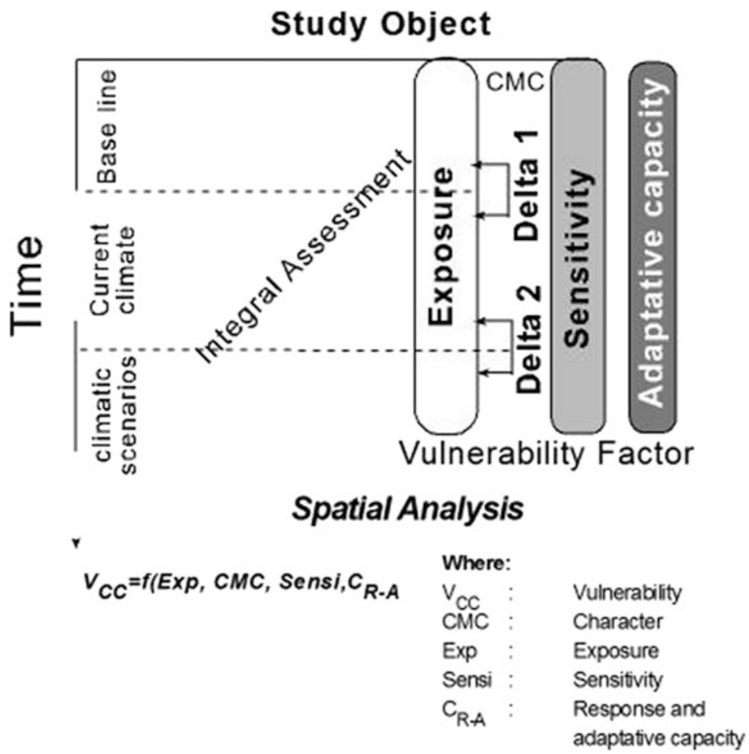


**Fig. 14.7** Study object approach to assessing time-space integral climate health vulnerability

vulnerability is being evaluated. In this case, the region is the basin of the Pilcomayo River in the Chaco.

The time-space behavior of socio-economic and hydrological variables, the condition of the ecosystem, epidemiology and responsiveness of the health system, among others, allow understanding the VCC for diarrhea ($VCC_{DD}$) in the Pilcomayo watershed. Each discipline follows specific methodologies within the research process and through a deconstructive process, furnishing constituent blocks important for health. These blocks follow a constructivist process for building $VCC_{EDAS}$ as a result from the interactions of vulnerability factors and dimensions for diarrheal diseases.

To set the climate regime of Chaco, a space-time analysis of meteorological variables was performed using data from each weather station as proposed by Ramallo (2006). Thus, several regional indexes were calculated to relate climatic anomalies with temperatures, precipitation and extreme events. The analysis on different time-scales allows identifying the main changes in climate seasonality and the relationship between interannual variability (VC) and ENSO.

The interannual variability was calculated as follows (Balme et al. 2006; Ramallo 2013):

$$\mathrm{Ii} = (\mathrm{Pi} - \mathrm{Pmoy})/\alpha$$

Ii = Precipitation indices in the year i
Pi = Annual precipitation in year i (mm)
Pmoy = Interannual precipitation (mm)
$\alpha$ = standard deviation of the studied period

Trends in precipitation and temperatures were calculated using the Pearson correlation and confidence levels at 95 %. They were used to explain the relationship between the annual rainfall and annual temperature with ENSO index.

Extreme events were selected from the average of the five most rainy or droughts years as threshold. This group of extreme events represents 15 % of total sample, which means that 1 year is characterized as extreme when surpasses 85 % of the total interannual average.

The seasonal variability analysis was made each 3 months linking the quarter and the annual rainfall (seasonal precipitation index = seasonal precipitation/annual precipitation/12). Thus, the seasonal cycle can be classified according to their annual cycle eliminating the influence of the annual rainfall (Espinoza et al. 2011).

In order to verify the water quality at each community samples in rural, peri-urban and urban regions were taken for bacteriological and physico-chemical tests at the UCCLIMAS laboratory and compared to the Bolivian standards.

Using the hydrological ChAc model (CEDEX 2006), the water offers were simulated for each community taking into account the soil and vegetation parameters to calculate the infiltration percentage in each basin (Ramallo 2006).

Future climates scenarios were generated with the LARS-WG stochastic model (Semenov 2014) which represents the extreme climatic events. Data generated are based on observed precipitation, maximum and minimum temperature, and radiation. The changes in probability function allow estimating the changes in extreme condition. For example, the probability of the maxima rainfall in climate change gives the needed information about the increase in magnitude and frequency of floods.

To characterize the basin, Pfafstetter methodology was used (Pfafstetter 1989), which assigns identifiers (IDs) for drainage units based on the topology of the ground surface. Each sub-basin was mapped and stakeholders were identified and selected, establishing relationships with water resource management entities.

To establish the water level baseline, a simulation was performed with the ChAc model (CEDEX 2006). After obtaining the flow of the studied sub-basins the simulation was performed using the data generated for the 2025 and 2050 Scenarios or Delta 2.

To compare different basins, the flow was converted into water level, so the influence of the size of basin was removed, using the following formula:

$$Le = \frac{V}{Area}$$

Where:

V = Volumen
A = Basin area

The formula was applied to the Pilcomayo Basin for future scenarios 2025 and 2050.

## Results and Discussion

Climate change is affecting the regional and local rainfall seasonal patterns; it is increasing the maximum and minimum temperatures, and climate variability and extremes. Although their current effects on water quality and availability are evident, in the long-term, without adequate climate change adaptation measures, this impact will be magnified (Aparicio-Effen et al. 2014).

### *Chaco Region Study Case*

Time-series of precipitation did not show significant trend in Chaco region, which is in agreement with the Andean and Amazonian regions (Seiler et al. 2012). However, a significant increase in temperatures' maxima and a decrease in the minima, especially in Villamontes, Carapari and Yacuiba, were found. These trends began around 1999, which likely increased some diseases. Thus, the populations of Chaco region are vulnerable to WBD as a consequence of the observed and projected climate scenarios on all the elements of an eco-health approach.

### *Near Future Climate Change Scenarios*

Climate change could be a major threat in the decades to come (Butler 2014)

Future climate scenarios generated with the LARS-WG stochastic model (Semenov 2014) for Chaco region show that increasing trends of minimum and maximum monthly and annual temperature are expected. The minimum temperature is expected to increase by 0.7 and 1.9 °C for 2020 and 2055 respectively. Maximum temperature is expected to increase by 0.9 and 2.1 °C for 2020 and 2055 respectively. The average monthly precipitation shows very small increase, which is not consistent across months and time-horizons (see also Nagy et al. 2015, showing some rainfall decrease according to recent IPCC RCP 4.5 scenarios).

### *Watershed and Water Availability*

Over the last few years, the population of Bolivian Chaco has increased as a consequence of economic growth based on oil exploitation, which in turn increased water demand. Also, the strong deforestation in head waters, the deviation of rivers used for agricultural activities and the waste of water for oil exploration are posing new threats to water offer-demand equilibrium.

The watersheds are suffering the direct effects of climate change on water availability and quality and the indirect ones due to other sectors. Water sources are contaminated. In the urban and peri-urban zones there are companies in charge of the distribution and quality of drinking-water. They have water treatment plants, so the water quality is better than in the rural zone where water is just disinfected but not treated. In these communities, consumption is from the river when there is no water available from the drinking-water network system (DWNS). Bacteriological contamination was found by the authors (unpublished results) in the rivers and the water sources which come from animals or from communities in the basin heads.

Using Precipitation-runoff CHAC model (CEDEX 2006), the outflows of 16 communities were simulated showing that more than 60 % of water consumption comes from underground water. During the rainy season (December-March), the aquifers are recharged which means that a change in the precipitation regime timing or quantity during these months, would impact the hydrological balance.

The comparison between climate baseline (1985–1999) and current climate (2000–2014), shows that in rural and urban communities, the trends in water resources are not significant. However, in peri-urban communities there is a decrease between 3 and 15 % depending on the size of the basin which is explained by the continuous growth of population that increases water demand, as well as deforestation, soil erosion and the degradation of natural resources.

In the upper watershed the availability of water resources depends mostly on underground water; the physiographic characteristics and the use of soil makes it a good place for a strong infiltration. Also, in the basin head waters, there are wetlands which are regulators of the hydrological balance. During the rainy season they are recharged and during the winter they gradually release the water. Wetlands surface (as NDVI Landsat images analysis) is about 7.1 $km^2$ in the basin head, 10 $km^2$ in the middle basin, and 5.2 $km^2$ in the lower basin.

The outflows are stronger linked to the precipitation from December-February with more that 50 % of the annual outflows. Precipitation-runoff CHAC model shows strong interannual outflow variability in both regions which is not necessarily linked to climatic anomalies like ENSO.

The five studied municipalities: Camiri, Machareti, Villamontes, Carapari and Yacuiba, are located in the Pilcomayo basin whose natural dynamics is dominated by the seasonal climate (Fig. 14.8), with alternating dry (May to October) and wet (December to March) seasons causing great variability of flows.

Most people in Chaco (80 %) depend on groundwater resources which are affected during dry years. Moreover, the increase in economic activities is producing a significant advance of the agricultural frontier and an increase of the population which results in new stresses on the hydrological cycle.

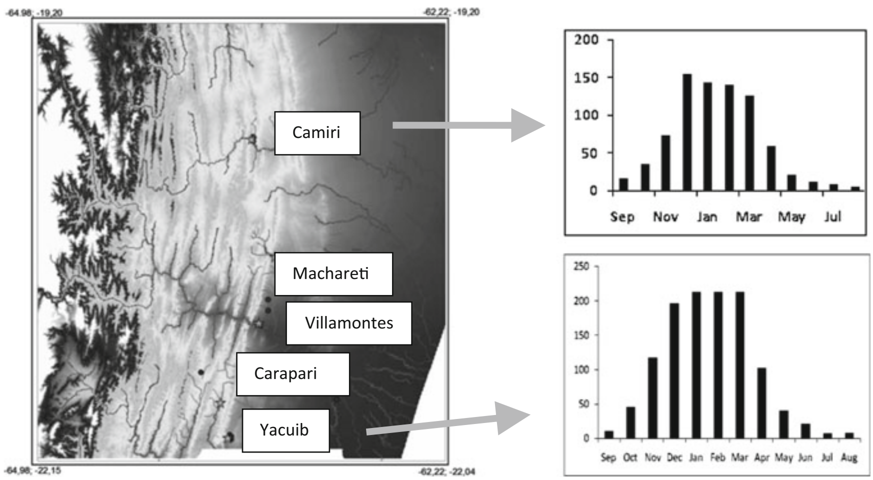


**Fig. 14.8** Chaco watershed hydrological map. *Points* show studied communities and *stars* municipal capitals. Rainfall at Southern and Northern Chaco Boliviano is shown. Source: digital elevation model (90 m resolution)

Twenty years ago the water balance was stable. However, at present and especially in the near future this resource could be at risk. This is mainly due to anthropogenic factors such as alteration of the upper basin, population increase and over-exploitation of natural resources.

## *Water Quality*

Physical, chemical, and bacteriological analysis (coliforms and *Escherichia coli*) were used to identify the degree of pollution for drinking-water in all communities included in this study and Pilcomayo River (Table 14.1) during humid and dry seasons.

The water samples showed that turbidity exceeded the permissible limits in most evaluated communities. Tiguipa and Boyuy rivers (Pilcomayo basin) had high levels of water pollution, with a major health risk to rural communities, especially in dry seasons or in frequent droughts, when drinking-water is taken from the rivers. The break in the water outlet is often associated with strong erratic rainfall events. Under a scenario of more extreme events in the near future (IPCC 2012), more frequent breaks of safe water supply are to be expected.

Rural and Peri-urban communities are more vulnerable to environmental bacteria and to *Escherichia coli* bacteria in humid and warm season, such as was the case in Peña Colorada and Avaroa that showed high levels of turbidity, total coliforms and *Escherichia coli*. These parameters are lower in dry season coincident with winter months (Table 14.2).

Parasitological analysis identified the presence of *Giardia lamblia* in water reservoirs of Tentamí (Guarani community). Lakes and rivers had organic levels above those permitted by Bolivian law, stronger in the rural and peri-urban communities (UCCLIMAS 2014).

**Table 14.1** Villamontes and Carapari Water River and home water taps samples results. Elaborated from the authors from CCLIMAS Laboratory results

| | River | | | Home water taps | | |
|---|---|---|---|---|---|---|
| Parameters | Boyuy River | Peña Colorada (Pilcomayo river | Carapari (Pilcomayo river) | Boyuy | Peña Colorada | Carapari |
| Turbidity (NTU) | 2.45 | 3.520 | 7.424 | 3.02 | 2.05 | 3.32 |
| Total coliforms (U.F.C./100 ml) | 9 | $7.5 \times 10^3$ | $2.5 \times 10^6$ | 7 | $5 \times 10^2$ | $5.5 \times 10^4$ |
| *Escherichia coli* (U.F.C./100 ml) | 9.2 | $2.4 \times 10^3$ | $1 \times 10^5$ | 5 | $7 \times 10^1$ | $1 \times 10^3$ |

**Table 14.2** Villamontes communities' water samples results for humid and dry seasons

| Parameters | Humid season | | Dry season | |
|---|---|---|---|---|
| | Peña Colorada | Avaroa (Tuntey) | Peña Colorada | Avaroa (Tuntey) |
| Turbidity (NTU) | 3.520 | 3.67 | 0.84 | 0.96 |
| Total Coliforms (U.F.C./100 ml) | $7.5 \times 10^3$ | $2.8 \times 10^1$ | 7 | 4 |
| *Escherichia coli* (U.F.C./100 ml) | $2.4 \times 10^3$ | 1 | <1 | <1 |

**Table 14.3** Chaco region vegetation coverage by type and size

| Plots | Neighborhood or community | Tree, shrub and grassland coverage | Leaf type: simple or compound | Plant leaves size—micro-foliated | NDVI |
|---|---|---|---|---|---|
| Urban | • Centro Sur<br>• Juan XXIII<br>• Virgen Fátima | Low | High | Low | Low |
| Peri-urban | • Fray Quebracho<br>• Barrio Nuevo<br>• Carapari, Avaroa,<br>• Tiguipa Estación<br>• Panamericano Alto | Medium | Medium | Medium | Medium |
| Rural | • Boyuy<br>• Palmar Grande<br>• Tentami<br>• Urundaity<br>• Purísima<br>• Tiguipa Pueblo | High | Low | High | High |

## *Head Watershed Ecosystem Results*

> Climate change is modifying ecosystems and it's creating the environmental condition for climate sensitive diseases occurrence (Confalonieri and Aparicio 2011)

The vegetation type and the presence of indicator species of different human intervention (urban, peri-urban and rural) were evaluated at 168 sampling points from 310 to 1060 m above sea level. The vegetation types are associated with Chaco Serrano region. The tree, shrub and grassland coverage, leaf type and size differences, and NDVI are shown in Table 14.3.

The ecosystem preservation status was also evaluated by the proportion of bird associations, identified species (71) and number of individuals (1756) by type of area. Rural areas showed fairly homogeneous guilds, indicating a well-preserved ecosystem, unlike urban areas where the predominant group was omnivorous.

More than 90 % of the analyzed species belong to disturbed habitats (fragmented forests, agricultural areas and secondary forests), representing agricultural rural and peri-urban areas.

## *Waterborne Transmissible Diseases*

In order to identify the causes of most frequent queries and WBD a retrospective analysis of 7 years and 200,284 clinical cases from Chaco (Yacuiba, Machareti, Camiri, Villamontes, and Carapari) Hospital was performed. Children from 0 to 5 years were most affected (51 %), followed by those from 5 to 20 years (20 %), from 20 to 59 years, (23 %) and from 60 to plus, (6 %).

Each disease was coded using the International Classification of Diseases (ICD-10) divided according to age groups. The most common diseases were constipation (K59, 0), abdominal pain (R10), gastroenteritis and duodenitis (K29), abdominal cramping pain (R10, 4), vomiting and nausea (R11), acute diarrheal disease—ADD S/D (A10,1)—and functional bowel disorder (K59,9), which are compatible with WBD and coincide with signs and symptoms most frequently reported by local population: pain, cramping, abdominal pain, diarrheas and constipation.

A clinical evaluation of all communities of who reported gastrointestinal diseases showed: diarrheal episodes (20 %), recurrent diarrhea (17 %), even 2–6 times per month, and diarrhea with mucus and/or blood (12 %). Diarrheas affected C.U.F. Y.O, with accumulated incidence of 34 % in 6 years. Machareti County showed the highest prevalence rate by 1000 C.U.F.Y.O.

The sources of drinking-water in Chaco are: DWNS (6.7–84 %), truck dealer (0.17–64 %), well (0.55–9.8 %), river or watershed (1.1–25.6 %), and another source (0.05–15.1 %). Accesses to basic services as toilet are low (21.16–44.6 %) and septic tank and well are used for stocks. Chaco infant mortality ranges from 43.28 to 54.87 %. In Carapari diarrhea is responsible for 39.25 % of infant deaths cause. Symptoms and cases of WBD were found in the whole watershed.

Water samples were taken from the DWNS, tanks, and home and community water storage. Water quality and parasitic analysis showed that several parameters were out National standards. Tiguipa community water taps samples were positive for *Escherichia coli* and Tentami water storage was positive for *Giardia lamblia* and *Eschericha coli*.

Most copro-parasitological samples in Chaco region showed high parasitism (88 %) (Table 14.4) related to viable cysts ingestion, contaminated water and food, lack of hygiene, poor socio-economic conditions, and poor water quality.

Diarrheas monthly seasonality shows cases all through year, including dry periods (coinciding with water quality deterioration) peaking during the rainy

**Table 14.4** Chaco's parasites type of copro-parasitological samples

| Category | Parasites | Positive samples (%) |
|---|---|---|
| Parasite | • *Eschericha coli* | 30 |
| | • *Blastocystis hominis* | 18 |
| Pathogenic parasites | • *Giardia lamblia* | 40 |

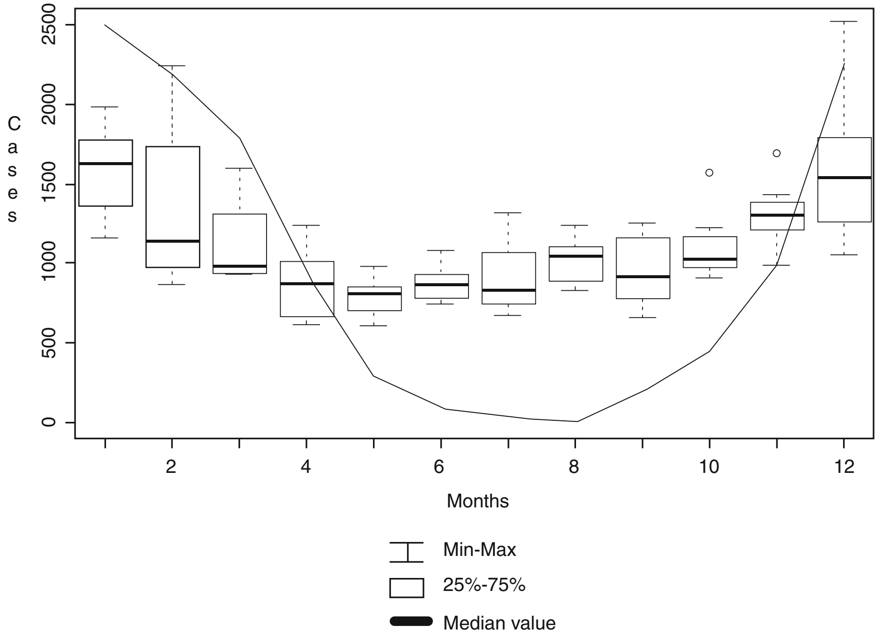


**Fig. 14.9** Chaco region's rain and number of cases of diarrhea seasonality. Elaborated by the authors from Ministry of Health database

period (November-April) (Fig. 14.9), high temperatures and relative humidity. The decrease in the number of cases is coincident with reduced rain and temperatures. The increases of Chaco's temperature and precipitation coincide with increased risks of parasite and microbiological factors.

## *Productive Assessment*

Climate change increases the likelihood appearance of many zoonotic diseases, whereas environmental changes allow for the development of new parasites and pests. Nevertheless, the health system net is not prepared to respond (Mills et al. 2010).

In Chaco summer time it is usual the death of livestock due to lack of food in the arid ecosystems with xerophytic vegetation. Droughts have strong impacts on livestock morbidity from September to December coincident with the highest temperatures related with livestock foot and mouth diseases.

### *Vulnerability Assessment*

The $VCC_{DD}$, assessment followed the proposed methodology (vulnerability dimensions and factors, and the causality between variables and the diarrhea cases number) where vulnerability dimension variables results were analyzed for all communities grouped in urban, peri-urban and rural. The correlation matrix values (1 high—0, 1 Low) from all positive and negative correlations were grouped in levels of vulnerability (high, medium and low) interacting with vulnerability factors assessment outputs.

The peri-urban correlation matrix (Fig. 14.10) shows that total coliform parameter in water samples is highly correlated with diarrhea cases number ($r$: +0.9). The *Escherichia coli* positive samples, which are associated with average maximum temperature increases (Delta 1) between past (1972–2000) and current (2001–2014) climate, are correlated with diarrhea cases (r: +0.6). The rainfall decrease is also correlated with *total coliforms* and diarrhea cases (r: +0.6). On the other hand a negative correlation was found between accesses to solid waste services collection, washing hands, hygiene practices with *total coliforms* and diarrhea cases number.

Table 14.5 summarizes $VCC_{DD}$ values resulting from vulnerability factors and dimensions scores for Chaco peri-urban communities. The character and magnitude of temperature changes are statistically significant ($p \geq 0.05$), whereas they are not for rainfall changes. However, due to temperature increases water loss is actually greater by evaporation.

The $VCC_{DD}$ are greater for the communities in the rural area of the Pilcomayo watershed: Machareti, Camiri and Carapari municipalities. The other localities evaluated including urban and some peri-urban areas show an intermediate level of $VCC_{DD}$ to climate change due to the decreasing availability and quality of water.

The occurrence of diarrhea is related to hygiene and sanitation especially in C.U. F.Y.O, being highly dependent on contaminated water sources, and the deficit in the management and disposal of solid waste.

*Escherichia coli* and/or *Giardia lamblia* were found in samples of tap water and water storage of various communities which coincided with high levels of $VCC_{DD}$. Parasitological analysis of soils in peri-urban areas of Yacuiba (Juan XXIII) was positive for *Ascaris lumbricoides*, *Strongyloides stercoralis* and/or *Trichuris trichiura* (Barrio Nuevo), which explains part of the intermediate level of $VCC_{DD}$ found in this municipality.

Rural communities in which the Guarani and Weenayek ethnicities are included, had higher rates of parasitism in relation to urban and peri-urban areas, but in general, the soils and waters of the studied area were highly contaminated with different types of parasites, cystis, fungus and bacteria (Table 14.6).

Local assessment, interviews with key stakeholders, municipal statistics, expert opinions and Knowledge, Attitudes and Practices (KAP) surveys (see also Aparicio et al. in this Book) were carried out among a representative number of stakeholders including urban, peri-urban and Weenhayek communities, aiming to understand social and environmental health determinants.

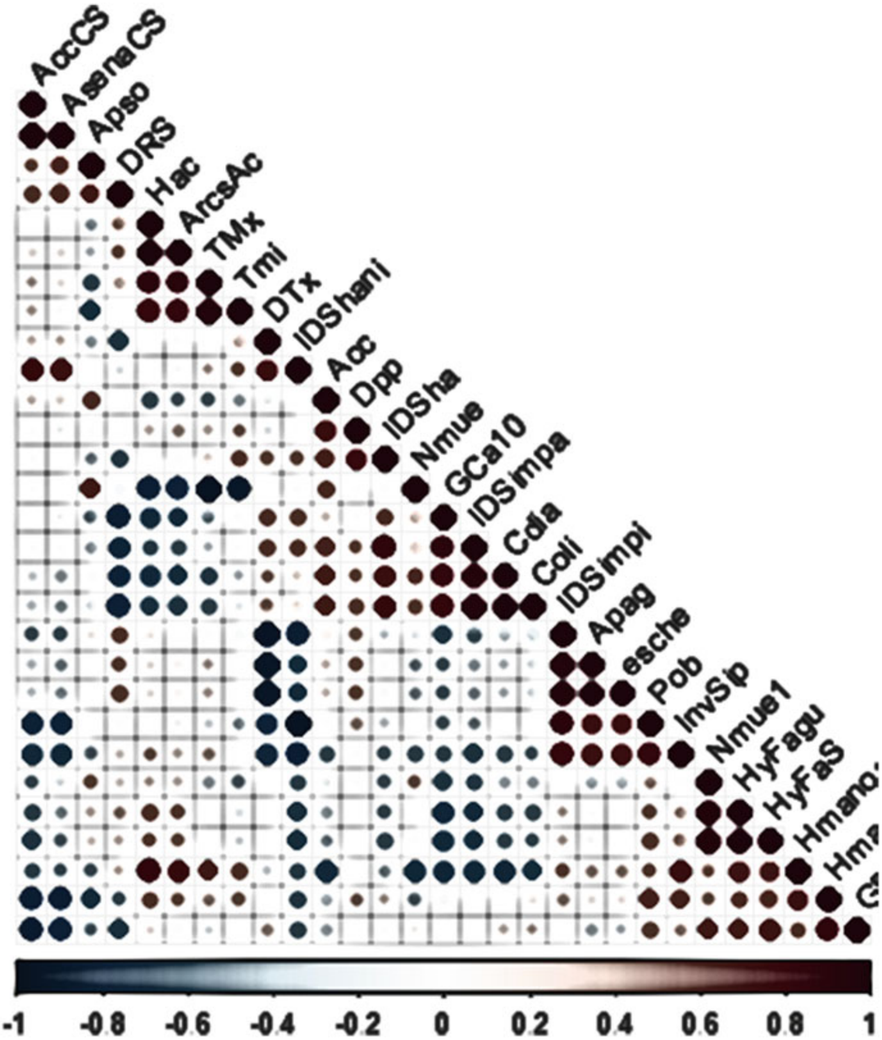


**Fig. 14.10** Chaco peri-urban communities' correlation matrix for diarrheas. Elaborated by the authors

**Table 14.5** Climate change vulnerability for diarrhea ($VCC_{DD}$) for Chaco peri-urban communities considering vulnerability factor and some evaluated dimensions

| Vulnerability factors | Vulnerability dimensions | | | |
|---|---|---|---|---|
| | Epidemiology | Hydrology | Social | Ecosystems |
| Exposure | 3 | 3 | 3 | 3 |
| Sensitivity | 3 | 3 | 3 | 3 |
| Character and magnitude of climate change | 3 | 2 | 3 | 3 |
| Adaptive capacity | 1 | 1 | 1 | 1 |
| **Total** | **10** | **9** | **10** | **10** |

$VCC_{EDAS}$ Levels: High (7–10), Medium (4–6) and Low (1–3), Elaborated by the authors

**Table 14.6** Chaco parasites type of water and soil analysis (UCCLIMAS Laboratory)

| Department | County | Community | Parasite positive |
|---|---|---|---|
| Santa Cruz | Camiri | Panamericano Alto | *Giardia* |
| Chuquisaca | Machareti | Tentami | *Giardia* |
| | | Tiguipa | *E. coli* |
| | | Boyuy | *E. coli* |
| | Yacuiba | Purisima Weenayek | Parasites' eggs and cystis, fungus, bacteria |

Indigenous communities with high rates of diarrhea have bad results in all indicators of physical and built environment (climate variables are the only ones similar for the three compared communities), human and social development, economic status, and intermediate results in governance. Thus, Weenhayek communities are highly vulnerable to climate health impacts. This critical situation in relation to socio-environmental factors in rural areas, as well as in peri-urban (moderate to high vulnerability) and urban areas (low to moderate vulnerability), is necessary to be addressed by authorities and communities itself in order to reduce WBD.

This status of the environment and services together with the KAP of the population, as well as weaknesses in the local adaptive capacity, increase the vulnerability of people in the Chaco against the effects of current climate variability and future changes.

## Adaptation Strategies

To cope with Bolivian high vulnerability a "National Adaptation to Climate Change Mechanism" (MNACC) was developed (PNCC 2007) which considers five priority sectors including human health. Some of the programmatic areas for human health adaptation are as follows:

- Mainstreaming of climate change policies and health programs in national and sub-national institutions.
- Identifying current and future vulnerability.
- Building capacities.
- Encouraging a pro-active attitude on the part of national health system and social participation}

Chaco region adaptation process is currently at a first stage of development which began with the vulnerability assessment results presentation to social, political, health sector, and stakeholders. This participatory approach allowed defining the better human health adaptation options in terms of measures, strategies, and adaptation policies.

The Chaco community-based adaptation focuses on the empowerment, equity, gender approach and promotion of communities' health resilience.

## Conclusions

The populations of Chaco regions are vulnerable to WBD and DD as a consequence of social, environmental and health determinants including the observed and projected climate scenarios

Chaco municipalities are suffering climate change and variability, as well as anthropogenic non-climate stressors, which cause health impacts such as waterborne transmissible diseases and diarrheal diseases. Evidences of these changes are: reduced water availability and quality; deteriorated watershed and ecosystems with both human and animal health consequences; decreasing rainfall and warming.

Near-future climate scenarios (2025–2050) project increases in temperature, whereas there is uncertainty with regard to rainfall (expected to be similar or less than current). Climate changes will likely affect the hydrological regime, human and environmental health, and economic activities in the Bolivian Chaco.

Occurrence of diarrheal diseases follows climate seasonal variability. The decrease in the number of cases coincided with the decrease in precipitations and the beginning of winter. This behavior seems to be related to observed climate change and variability impacts.

Occurrence of WBD is high in Chaco due to both water availability and quality. Oil exploitation drives population immigration to peri-urban areas increasing water demand, deforestation, rivers diversion, and agricultural frontiers advancement.

Water for human consumption is contaminated with parasites, bacteria and fecal coliforms in all sub-systems of drinking-water which produces high levels of WBD.

Despite the numerous programs developed to prevent Acute Diarrheal Diseases and the increased knowledge about their biological causes, there is a strong flaw in ecosystems status and hydro-climatic factors, and how they interact with other factors that reduce or increase diseases incidence.

The ecohealth approach shows that climate and ecosystem changes are increasing the sensitivity to developing WBD with observed impacts on both human and animal health, and livelihood.

The understanding of the increasing impacts of climate change and variability on water issues is a call for collective action to resolve the lack of access to clean water based on integrated management of water resources. The isolated actions of the health sector are insufficient to meet the challenge of providing safe water to the most vulnerable.

## References

Aparicio M (2010) Evaluación de la vulnerabilidad sanitaria nacional y subnacional al cambio climático (incluida su variabilidad), como base para el diseño e implementación de medidas de adaptación. Organización Panamericana de la Salud/Organización Mundial de la Salud. Available at www.ops.org.bo/textocompleto/clima32340.pdf and http://www.who.int/mediacentre/factsheets/fs266/en/

Aparicio M, Aparicio J, Trujillo F, Chavez R, Rodriguez J, Lima E, Muñoz M, Halborsen K (2007) High altitude malaria outbreak in the Lake Titicaca region. In: Devisscher T, O'Brien G, O'Keefe P, Tellam I (eds) The adaptation continuum (groundwork for the future). Stockholm Environment Institute, Luesden, pp 66–67. www.climasaludlac.org/avisos/50-adaptacion-cambio-climatico-salud.html. Accessed 7 Apr 2015

Aparicio-Effen M, Espejo E, Torres M, Aparicio J, Ramallo C (2014). Cambio Climático, Agua y Salud. Aparicio-Effen M (ed) La Paz. ISBN:978-99954-2996-6. 147 pp

Aparicio-Effen M, Arana I, Aparicio J, Cortez P, Coronel G, Pastén M, Nagy GJ, Galeano Rojas A, Flores L, Bidegain M (2015) Introducing hydro-climatic extremes and Human Impacts in Bolivia, Paraguay and Uruguay. In: Leal Filho W, Alves F, Azeiteiro UM (eds) Climate change and health: improving resilience and reducing risks. Springer, Cham

Báez J, Monte Domecq R, Lugo C (2014) Risk analysis in transboundary water of the rivers Pilcomayo and Paraguay. Chapter 2. In: Leal Filho W, Alves F, Caeiro S, Azeitierio UM (eds) International perspectives on climate change: Latin America and beyond, Climate change management. Springer, Cham, pp 19–29. doi:10.1007/978-3-319-04489-7_2. ISBN 978-3-319-04488-0

Balme M, Lebe T, Aman A (2006) Années sèches et années humides au Sahel. Hydrol Sci J 51:254–271, Available at www.amma-international.org/IMG/pdf/ISP2_v2.pdf. Accessed 6 Apr 2015

Berry HL (2007) "Crowded suburbs" and "killer cities": a brief review of the relationship between the urban environment and mental health. NSW Public Health Bull 18(11–12):222–227

Borbor-Cordova MJ, Hayden M, Saltzmann N, Stewart A (2008) Climate, environment and health: applying a contextual ecohealth approach. NCAR, Institute for the Study of Society and Environment, 32 pp. Available at www.asp.ucar.edu/pdfp/doc/compborbor08.pdf. Accessed 3 June 2015

Bush MB, Hanselman JA, Gosling WD (2010) Nonlinear climate change and Andean feedbacks: an imminent turning point? Global Change Biol 16:3223–3232

Butler C (2014) Nuclear Australia. Available at nuclearnewsaustralia.wordpress.com/page/32/

CEDEX (2006) Manual Calculo Hidro meteorologico de aportaciones y crecidas (C.H.A.C.) Ministyerio de fomento, Ministerio de Medio Ambiente; Centro de experimentacion en obras públicas de España pp 42

Charon D (2012) Ecohealth research in practices. IDRC-CRDI, Springer, Ottawa, Accessed 31 Mar 2015

Confalonieri UEC, Marinho DP (2005) Remote sensing and the control of infectious diseases: proceedings of an interamerican workshop. ENSP/FIOCRUZ, Rio de Janeiro, 104 pp

Confalonieri U, Aparicio M (2011) Overview of how ecosystem changes can affect human health. In: Nriagu JO (ed) Encyclopedia of environmental health. Elsevier, Amsterdam, Five-Volume Set. 5016 pp

Cortez P (2005) Cambios sociales y culturales en el pueblo indígena Weenhayek en los últimos cincuenta años. CERDET, Tarija, Available at www.ftierra.org/index.php?option=commtree&task=att. Accessed 3 Apr 2015

EcoHealth (2014) EcoHealth 2014 call to action EcoHealth and climate change: connections for health, ecosystems and society, Cinbiose and Co-PEH, UQAM, Canada. Available at www.ecohealth-live.net. Accessed 7 June 2015

Erickson CL (1988) Raised field agriculture in the Lake Titicaca Basin: putting ancient agriculture back to work. Expedition 30:8–16

Espinoza JC, Ronchail R, Lavado W, Carranza J (2011) Spatio-temporal rainfall variability in the Amazon basin and its relationship to regional hydrological variability. A particular focus in the Andean region. Revista Peruana Geo-Atmosférica (RPGA) 2:99–130, Available at www.lamolina.edu.pe/Investigacion/web/Revistas.../agricola.html. Accessed 4 June 2015

Francou B, Vincent C (2007) The glaciers will disappear. Glaciers to climate change. IRD and CNRS Editions, Berlin, Available at www.researchgate.net/...Climate_change...glaciers. Accessed 6 June 2015

Hales S, Kovats, S, Lloyd, S, Campbell-Lendrum D (2014) Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s. ISBN:9789241507691 Geneva: World Health Organization; 2014. pp. 1–128.

Hanley A (2007) Diabetes in indigenous populations. Medscape Today. Available at http://www.medscape.org/viewarticle/540921. Accessed 15 Mar 2015

Hassan R, Scholes R, Ash N (2005) Ecosystems and human well-being: current state and trends, vol 1. Finding of the condition and trends working group of the Millennium Ecosystem Assessment. Island, Washington, DC, Available at www.unep.org/maweb/.../document.766.aspx.pdf. Accessed 15 June 2015

Health Canada (2013) Facts on suicide rates, first nations and Inuit health. Available at http://www.hc-sc.gc.ca/fniah-spnia/promotion/suicide/index-eng.php

Hunter PR (2003) Climate change and waterborne and vector-borne disease. J Appl Microbiol 94:37S–46S

Ibisch PL, Beck SG, Gerkmann B, Carretero A (2003) Ecoregiones y ecosistemas. In: Ibisch P, Mérida G (eds) Biodiversidad: La riqueza de Bolivia. Estado de conocimiento y conservación. Fundación Amigos de la Naturaleza, Santa Cruz de la Sierra, pp 47–88, Available at www.scielo.org.bo/scielo.php?pid=S1605-25282006001000004. Accessed 15 June 2015

IPCC (2007) Summary for policymaker. In: Parry ML, Palutuikof JP, van der Linden PJ, Hanson CE (eds) Climate change 2007: impact adaptation and vulnerability. Contributing Working Group II to IPCC Four Assessment Report. Cambridge University Press, Cambridge, UK, 114 p. ISBN 92-9169-321-9

IPCC (2012) Managing the risks of extreme events and disasters to advance climate change adaptation: special report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK

IPCC (2014a) In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds) Climate change 2014: impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, 1132 p

IPCC (2014b) In: Barros VR, Field CB, Dokken DJ, Mastrandrea MD, Mach KJ, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds) Climate change 2014: impacts, adaptation, and vulnerability. Part B: Regional aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, 688 p

IWGIA (2006) The International Work Group for Indigenous Affairs. The indigenous world 2006. Stidsen S (ed). ISSN:1024-0217, ISBN:87-91563-18-6, Prepress and Print: Eks-Skolens Trykkeri, Copenhagen, Denmark. 543 pp. Accessed 9 June 2015

Killeen TJ, García E, Beck S (1993) Guía de Árboles de Bolivia. Herbario Nacional de Bolivia–Missouri Botanical Garden, La Paz

Kolstad E, Johansson KA (2011) Uncertainties associated with quantifying climate change impacts on human health: a case study for diarrhea in research. Environ Health Perspect 119 (3):299–305

Lessem R, Schieffer A (2010) Integral economics. Gower, Farnham, 412 pp. http://www.buckingham.ac.uk/research/publications/integral-economics-farnham-gower-2010/. Accessed 4 June 2015. ISBN 978-0-566-09247-3

Londoño A, Levis S, Rodas J (2011) Hantavirus como agentes emergentes de importancia en Suramérica. Biomédica 31:451–464

Magrin G, Marengo J, Boulanger JP, Buckeridge M, Castellanos E, Poveda G, Nobre C, Scarano F, Vicuna S (2014) Central and South America, Chap. 27. In: Climate change 2014: impacts, adaptation and vulnerability. Part B: Regional aspects. Contribution of Working Group II to the fifth assessment report of the Intergovernmental Panel on Climate Change IPCC, 2014. Cambridge University Press, Cambridge, pp 1499–1566. ISBN:978-1-107-68386-0. http://ipcc-wg2.gov/AR5/report/citations/. Accessed 25 Jan 2015

Mills JN, Gage KL, Khan AS (2010) Potential influence of climate change on vector-borne and zoonotic diseases: a review and proposed research plan. Environ Health Perspect 118 (11):1507–1514, Published online 2010 Jun 24. doi: 10.1289/ehp.0901389. Available at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2974686/. Accessed 4 June 2015

Morin E (2007) Introducción al Pensamiento Complejo. Available at http://www.pensamientocomplejo.com.ar/docs/files/MorinEdgarIntroduccion-al-pensamiento-complejoParte1.pdf. Accessed 6 June 2015

Nagy GJ, Caffera RM, Aparicio M, Barrenechea P, Bidegain M, Jiménez JC, Lentini E, Magrin G et al (2006) Understanding the potential impact of climate change and variability in Latin America and the Caribbean. Report prepared for the Stern Review on the Economics of Climate Change, 34 pp. Available at http://www.sternreview.org.uk. Accessed 4 Jan 2015

Nagy GJ, Coronel G, Pastén M, Báez J, Monte-Domecq R, Galeano Rojas A, Flores L, Ciganda C, Bidegain M, Aparicio-Effen M, Arana I, Aparicio J (2015) Impacts on well-being and health by excessive rainfall and floods in Paraguay, Uruguay and Bolivia. In: Leal Filho W, Alves F, Azeiteiro UM (eds) Climate change and health: improving resilience and reducing risks. Springer, Cham

NOAA (2015) Oceanic Niño Index. http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml. Accessed 15 Feb 2015

PAHO (2002) La Salud en las Américas, vol 1, 181 pp. Pan American Health Organization. Available at www.paho.org/hq/index.php?option=com_docman&task=doc. Accessed 3 Mar 2015

PAHO (2011) Pan American Health Organization. Available at http://www.paho.org/hq/index.php?option=com_content&view=article&id=5172&Itemid=3757. Accessed 5 Feb 2015

PAHO (2014) Acerca de Rotavirus. Pan American Health Organization. Available at http://www.paho.org/hq/index.php?option=com_content&view=article&id=1861:about-rotavirus&Itemid=1621&lang=pt. Accessed 10 Feb 2015

Parashar UD, Hummelman EG, Bresee JS, Miller MA, Glass RI (2003) Global illness and deaths caused by rotavirus disease in children. Emerg Infect Dis 9(5):565–572

Pfafstetter O (1989) Classification of hydrographic basins: coding methodology, unpublished manuscript, Departamento Nacional de Obras de Saneamento, 18 Aug 1989, Rio de Janeiro; available from J.P. Verdin, U.S. Geological Survey, EROS Data Center, Sioux Falls, South Dakota 57198, USA. Available at www.nssl.noaa.gov/projects/basins/pfaf.ppt. Accessed 4 June 2015

PNCC (2007) Mecanismo Nacional de Adaptación al Cambio Climático (MNACC), Bolivia. Programa Nacional de Cambio Climatico (PNCC). Available at www.iteresources.worldbank.org/INTCC/Resources/MecanismoNacional. Accessed 28 Feb 2015

Ramallo C (2006) Aplicación de la imagen satelital Aster y del modelo hidrologico Hec Geo Hms para la modelación de una cuenca de alta montaña: caso Llaullini. Tesis Universidad Mayor de San Andrés, La Paz. Ingenieria Geografica. Available at observatoriogeograficoamericalatina.org.mx/egal11/.../02.pdf. Accessed 2 June 2015

Ramallo C (2013) Caracterisation pluviometrique et sa relation aux debits du glacier du Zongo. Tesis doctoral, Universite Joseph Fourier, Grenoble. Available at www.lthe.fr/PagePerso/boudevil/THESES/ramallo_13.pdf. Accessed 3 June 2015
SDWF (2015) The effect of climate change on waterborne diseases. Safe Drink Water Foundation. Available at http://www.bvsde.paho.org/bvsacd/cd68/ effectclim.pdf. Accessed 20 Feb 2015
Seiler C, Hutjes R, Kabat P (2012) Climate variability and trends in Bolivia. J Appl Meteorol Climatol 52:130–146
Semenov MA (2014) LARS-WG stochastic weather generator. Rothamsted Research, Harpenden, Hertorfdshire, AL5 2JQ, UK. Available at http://www.rothamsted.ac.uk/mas-models/larswg.php. Accessed 8 Mar 2015
Shuman EK (2010) Global climate change and infectious disease. N Engl J Med 362:1061–1063
Singh RB, Hales S, de Wet N, Raj R, Hearnden M, Weinstein P (2001) The influence of climate variation and change on diarrheal disease in the Pacific Islands. Environ Health Perspect 109 (2):155–159, Available at www.ncbi.nlm.nih.gov/pubmed/11266326. Accessed 11 Mar 2015
Smith KR, Woodward A, Campbell-Lendrum D, Chadee DD, Honda Y, Liu Q, Olwoh JM, Revich B, Sauerborn R (2014) Human health: impacts, adaptation, and co-benefits. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, Mac Cracken S, Mastrandrea PR, White LL (eds) Climate change 2014: impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, pp 709–754
UCCLIMAS (2014) Informe de Laboratorio. Unidad de Cambio Climático Ambiente y Salud (UCCLIMAS). Unpublished report
Watson JT, Gayer M, Connolly MA (2007) Epidemics after natural disasters. Emerg Infect Dis 13 (1):1–5, Available at www.cdc.gov/eid
WHO (2010) Hidden cities: unmasking and recovering health inequalities in urban settings. World Health Organization, Centre for Health Development (Kobe). ISBN:9789241548038. Available at http://www.who.int/kobe_centre/publications/hiddencities_media/who_un_habitat_hidden_cities_web.pdf. Accessed 6 June 2015

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