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Abstract

Purpose – Climate change and variability are both a developmental and an environmental issue. Adaptation to climate change and variability has gained a prominent place on global and local policy agendas, evolving from mainly climate risks impacts and vulnerability assessments to mainly adaptation action, imposing new defies to higher education (HE). The purpose of this paper is to introduce the Climate Vulnerability, Impact, and Adaptation (VIA) Network (CliVIA-Net), a South American university-based coalition aimed at achieving a science for/of adaptation.

Design/methodology/approach – CliVIA-Net is a collaborative effort by academic groups from across the spectrum of the natural, social and health sciences focused on improving climate VIA on education, research and practice. In consonance with international literature and practices, the network shifted from a discipline-oriented approach to an interdisciplinary and Earth System Science (ESS)-oriented one. It seeks to advance fundamental understanding and participatory practice-oriented research and to develop a problem orientation question/solving answering methodology. A set of cases studies illustrates how CliVIA-Net faces adaptation and sustainability challenges in the twenty-first century.

Findings – Focusing on interdisciplinary graduate education, practice-oriented research and problem orientation practice on climate threats which are already threatening the environment, population's well-being and sustainability, allows for the co-production of knowledge and solutions, as well stakeholders' buy-in and commitment.

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Originality/value – CliVIA-Net draws upon the results of evolving interdisciplinary approaches on global change and VIA education, the research partnership with stakeholders and decision-makers to develop environmental and health outcomes, e.g. vulnerability indicators and scenario planning.

Keywords South America, Higher education, Adaptation, Practice-oriented research, Problem-oriented, VIA indicators

Paper type Case study

1. Introduction

As society faces unprecedented and increasingly urgent challenges associated with accelerating global environmental change and its impacts, and increasing inequality, new opportunities for higher education (HE) are emerging throughout the world to be change agents for sustainability including goals on climate change, growth and health (Stephens *et al.*, 2008; Barth, 2015). Several institutions and groups are already very active in climate change research, and teaching that is arguably part of wider sustainability science efforts worldwide (SARUA, 2010).

The United Nations defined the period 2005-2014 as the decade "for sustainable development", which incorporates the fundamental issues of sustainable development for teaching and learning, e.g. climate change and disaster risk reduction (DRR) (UNESCO, 2011; UN-DESD, 2014). Climate change and variability are increasingly recognised as both a developmental and an environmental issue. Such a situation calls for mainstreaming climate change adaptation into development policies (UNESCO, 2016).

The role of HE to face the challenges of climate change and variability may be synthesised in three main issues:

(1) interdisciplinary formation of researchers and managers;

(2) change of research focus from disciplinary-oriented to social emergent problems-oriented; and

(3) as a consequence of the involved behavioural, cultural and socioeconomic aspects, climate change education and research have closer links with society than its original disciplines (National Academies, 2003; UNESCO, 2011).

Many universities are implementing new interdisciplinary climate change curricula towards sustainable development (Altbach *et al.*, 2009; Second Nature, 2011; Rieckmann, 2012).

Those involved in producing knowledge to solve societal problems face three particular challenges:

(1) complexity of real-world sustainability problems;

(2) maintaining impartiality when expert knowledge is used in decision-making; and

(3) ensuring the salience of the scientific knowledge for decision-makers.

Three strategies to meet these challenges are:

(1) interdisciplinarity;

(2) partnership with decision-makers, stakeholders and non-academic experts; and

(3) framing research questions aimed at solving specific problems (problem orientation) (Kueffer *et al.*, 2012).

The overall question, goal and objectives of this article are based on some needs, as per the authors' assessment, to fill the gaps between the academia and society in Bolivia, Paraguay,

Uruguay and Venezuela with regard to climate change and variability adaptation. These needs are to increase:

- interdisciplinarity;
- number of graduated researchers who can integrate global changes knowledge and data;
- participatory approaches to climate change and variability management; and
- role of academia in solving societal challenges, e.g. climate variability and extremes.

Overall question: How should the academia face challenges posed by a changing climate on the natural and human environment?

Goal: To introduce the approach for education, research and practice (ERP) undertaken by the Climate Vulnerability, Impact and Adaptation Network (CliVIA-Net) (Table I).

Objectives: The objectives are to:

- highlight the foundation concepts and approaches of the network as used in this article;
- present five education-, research- and/or practice-focused case studies and how they include the key concepts; and
- achieve a "science for/of adaptation".

The methodological approach of this article consists of a series of case studies undertaken by academic coalitions, and discussions to create a network linked by similar climate-related problems to be solved at the academic level. It relies on both foundation concepts and a sequence of reasoning for solving them, which is expressed in the form of five case studies.

2. Definitions of key terms and foundation concepts

The definitions of the key terms and foundation concepts are explained as used herein. They are as follows:

- *Adaptation* (A): "Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (UKCIP, 2014).
- *Sustainability* (Sust): "Sustainability involves devising a human society which ensures their quality of life in ways which simultaneously protect and enhance the earth's life support systems under the principles, values, and practices of

Undergraduate	Graduate level	Research and practice
Scientific knowledge	Methodology	Scientific knowledge and evidence-based interdisciplinarity for taking action
Disciplinarity	Interdisciplinarity	Practice-oriented and problem-oriented research with stakeholder participation, e.g. CBA and EcoHealth
Diversity	Interdisciplinarity and Earth System Science-based VIA	Co-production of knowledge and solutions
Oriented trend	Problem-solving approaches	Science of/for adaptation

Table I. Current approaches of CliVIA-Net: Undergraduate and graduate higher education levels, research and practice

sustainable development into all aspects of education and learning"(World Commission on Environment and Development, 1987; UN-DESD, 2014).

- *Interdisciplinary research* (IDR): "A process of answering a question, solving a problem, or addressing a topic that is too broad or complex to be dealt with adequately by a single discipline or profession" (Klein and Newell, 1998).
- *Earth System Science* (ESS): "The application of systems thinking to Earth sciences which provide a physical basis for understanding the world in which we live and upon which humankind seeks to achieve sustainability" (Ruzek, 2007). "It is based on highly interdisciplinary research, demanding a broad basic knowledge of the different research aspects, their feedbacks, and interconnections" (Grossfeld *et al.*, 2013).
- *Participatory Practice-oriented Research* (PoR): "Involves inquiry into the methods, systems, programs, and policies of professional practice. In a case study context, this means an investigation of a particular example, or case, related to some aspect of practice. The goal of the practice-oriented research is to utilize research knowledge to enhance the development and implementation of practice and policy" (Marshall, 2010) [. . .] [It] relates to projects that focus on the connection between research and practice "From knowledge into taking action" including bottom-up and top-down actions, local and scientific knowledge, and a vast array of stakeholders, such as Disaster Risk Reduction-DRR practitioners **(**Gaillard and Mercer, 2013).
- *Problem orientation* (Po): "The quest to formulate research questions that are most likely to provide the answers that actors need" (Kueffer and Hirsch Hadorn, 2008).
- *Community-based adaptation* (CBA): "Community-based adaptation operates at the local level in communities that are vulnerable to the impacts of climate change. It identifies, assists, and implements community-based development activities that strengthen the capacity of local people to adapt to living in a riskier and less predictable climate" (Ayers and Forsyth, 2009).
- *EcoHealth*: An Ecosystem approach to health for a global sustainability agenda. "A field of research, education, and practice that impulse transdisciplinary frameworks of health-research and partnership projects with stakeholders and affected communities with a view to developing environmentally sustainable, community-based interventions to improve the health of affected communities" (Charron, 2012; EcoHealth, 2014).
- *Science for/of Adaptation* (SofA): The authors understand that the following comprehensive statement of Swart *et al.* (2014) blends many of the definitions presented above and the goals of CliVIA-Net: "Participatory, practice-oriented research with strong stakeholder participation has to be complemented by and connected to knowledge that has been developed in disciplinary sciences. There is a need of a Science of/for Adaptation (SofA). The level and method of participation in SofA should be determined on the basis of the specific project context and goals. More emphasis on the science of adaptation can lead to improved understanding of the conditions for successful science for adaptation".

3. CliVIA-Net development, academic groups, approaches and programmes

3.1 Development of CliVIA-Net, academic groups and objectives

The CliVIA-Net is a university-based initiative virtually located at the Facultad Politécnica, Universidad Nacional de Asunción (FP-UNA), San Lorenzo, Paraguay.

CliVIA-Net is developing collaborative interdisciplinary ERP across the spectrum of natural, health and social sciences to face the challenges posed by the increasing climate and environmental changes, ENSO variability, hydro-climatic disasters, and sustainability (Box 1).

The academic groups and programmes of CliVIA-Net are as follows:

- Master of Science in Global Change (MGC). Facultad Politécnica, Universidad Nacional de Asunción, San Lorenzo, Paraguay (FP-UNA).
- "Cátedra Libre" (Free Chair) of Climate Change in Venezuela (CLCC). Universidad Central de Venezuela (UCV) and Universidad Simón Bolívar (USB) Caracas, Venezuela.
- Climate EcoHealth (Clim-EcoHealth) and Vulnerability Index (CEHV-I). Climate Change and Environmental Health Unit (UCCLIMAS), Instituto Boliviano de Biología de Altura, Facultad de Medicina (IBBA), Universidad Mayor de San Andrés (UMSA), La Paz, Estado Plurinacional de Bolivia.
- VIA Assessment in Coastal Areas of South America (SAVIA-Coast), Universidad Simón Bolívar (USB), Venezuela, and Facultad de Ciencias, Universidad de la República (FC-UdelaR), Uruguay).
- Scenario Planning ("Thinking of Futures" or participatory scenario planning [PSP]). Facultad de Ciencias, Universidad de la República (FC-UdelaR), Uruguay, Universidad Simón Bolívar (USB), Venezuela, and CliVIA-Net.

The main objectives of CliVIA-Net are to:

- Improve interdisciplinarity and ESS graduate-level education to address climate change and variability threats, environmental change and DRR, particularly in relation to ENSO events.
- Influence decision-making at local and regional levels.
- Integrate climatic, environmental and health sciences with socio-economic information.
- Assess climate VIA focused on monitoring and evaluation systems.
- Achieve dialogue between local and academic knowledge to co-produce solutions to questions in partnership with stakeholders.

Box 1. Background and development of CliVIA-Net

The CliVIA-Net is a by-product of the development of the Master of Science in Global Change (MCG) of the FP-UNA from 2011-14 (Coronel *et al.*, 2015).

CliVIA-Net builds upon previous experiences intended to cooperate on global change, climate risks, vulnerability assessments and indicators and adaptation initiatives in communities (Ferrara de Giner *et al.*, 2012), water resources (Coronel *et al.*, 2015), well-being and health in relation to climate extremes in Bolivia, Paraguay and Uruguay (Aparicio-Effen *et al.*, 2016a, 2016b; Nagy *et al.*, 2016), and in coastal areas of South America (Villamizar *et al.*, 2016).

The network was formalised in 2016 (http://clivianet.poliagile.com/). This coalition includes academic groups and programmes from Bolivia, Paraguay, Uruguay and Venezuela, aimed at developing a collaborative network on VIA education, research and practice.

3.2 Education, research and practice approaches

CliVIA-Net programmes focus on IDR, partnership with stakeholders and decision-makers and Po. Examples of integrative top-down ESS-based and bottom-up experiences are PoR and Po) approaches.

A major difficulty in cross-disciplinary science is to find a proper common language, where people from different disciplines can explain their research question and contribute to solution strategies. Consequently, these gaps are filled by providing scientific education and basic and expert knowledge on ESS (Grossfeld *et al.*, 2013).

All the programmes include an overall goal or question, their approaches and how they deal with the foundation (key) concepts. For instance, adaptation, IDR and sustainability are common to all groups; Earth System Education (ESSE), PoR and IDR are central to the education initiatives (CLCC and MGC), whereas PoR and Po are the main research approaches of Clim-EcoHealth and CEHV-I programmes (Bolivia). CBA and EcoHealth were adapted from the literature and international cooperation at CLCC and Clim-EcoHealth, respectively, inspiring the recently developed programmes SAVIA-Coast and CEHV-I. Finally, the concept of science for/of adaptation was adopted as the leading idea of the academic network and of (for) this article.

The main approaches and research lines of CliVIA-Net are summarised in Box 2.

4. CliVIA-Net programmes and case studies

Five case studies of academic groups and programmes of CliVIA-Net are presented aimed at showing different education, research and practice experiences on climate change and variability vulnerability, impact and adaptation.

4.1 MSc in Global Change, FP-UNA, Paraguay

> Emphasis must be put on building capacity to develop a community of experts in Climate Science Management and the co-production of knowledge aimed at increasing public awareness and trust, through a participatory and informed process (Coronel *et al.*, 2015).

The MSc in Global Change (MCG) is a university-based effort from across the spectrum of the natural and social sciences, engineering and health at the Facultad Politécnica of the Universidad Nacional de Asunción (FP-UNA), Paraguay. This programme was developed in

Box 2. ERP approach and research lines of CliVIA-Net groups

The ERP approaches, research lines and activities of CliVIA-Net are as follows:

- ESSE, systems thinking (MGC, CLCC).
- CBA and Eco-health to co-produce knowledge and to solve emergent climate-related environmental problems (CLCC, Clim-EcoHealth, CEHV-I).
- Education for sustainable development and links with adaptation (MGC, CLCC).
- Global climate models – GCMs – and representative concentration pathways – RCPs (PSP).
- Hydroclimatic variability, extremes and disaster risk reduction (DRD) (CLCC, Clim-EcoHealth, CEHV-I).
- Observed and potential impacts associated with ENSO variability and outcomes from GCMs (CLCC, Clim-EcoHealth, CEHV-I, SAVIA, PSP).
- Shared socio-economic pathways (SSPs) and PSP.
- Vulnerability, impacts and adaptation assessments of coastal areas focused on sea level rise (SLR) and storm surges; hydroclimatic extremes focused on floods, landslides, well-being and health (CLCC, SAVIA, PSP).

2014 aimed at being an agent for sustainability and climate change teaching and research, a worldwide trend proposed by Barth (2015) and UNESCO (2016).

The goal of the MGC is to build capacity on global change, climate variability, climate risks and VIA assessments to conduct research and practice framed on the principles of sustainability linked with ESS, IDR, Po and CBA approaches. Curricula seek to develop common scientific language and basic knowledge across disciplines to face the challenge of filling the gaps among disciplines, and between the academia and society, as suggested by Rieckmann (2012) and Grossfeld *et al.* (2013).

Ongoing experiences are focusing on the application of systems thinking and inquiry-based approaches to teaching and learning about the interactions between Earth Systems and climate risks (e.g. floods, vector-borne diseases).

Graduated practice-oriented researchers and problem-oriented practitioners might be able to understand climate risks and be able to analyse, produce and/or manage climate and socio-economic scenarios, VIA assessments, environmental changes, hydroclimatic variability and extremes and well-being in Paraguay and the Rio de la Plata river basin. Emphasis is given to the links between adaptation options, intra- and intergenerational equity and sustainability.

Studies by Coronel *et al.* (2015); Aparicio-Effen *et al.* (2016b) and Nagy *et al.* (2016) are the supporting literature.

4.2 Cátedra Libre of Climate Change (CLCC-UCV), UCV and USB, Caracas, Venezuela

The *Cátedra Libre* of Climate Change (CLCC) of the Universidad Central de Venezuela (UCV) (CLCC-UCV) was developed in 2008 according to the objectives of the UNFCCC Article 6: "Awareness improvement on climate change in all community levels", and followed the working programme of the "Capacity Building for Stage II Adaptation to Climate Change" (UNEP, 2012).

The ongoing experiences from CLCC focus on expanding frontiers for researchers and stakeholders to better understand climate change adaptation framed on the principles of sustainability linked with IDR, ESS and CBA approaches. The main challenge faced by the programme is mainstreaming adaptation into local development plans.

ESS and CBA approaches are central in ERP ongoing activities at CLCC. The former seeks to improve knowledge of the effects of climate change and variability providing sustainable solutions to effectively reduce the impacts of a changing climate. The latter links adaptation with development and considers that adaptation strategies must be generated through participatory processes and mainstreaming adaptation into development policies, rather than being restricted to impact-based scientific inputs alone (Ayers and Doldman, 2010; Reid, 2016).

The CLCC has integrated bottom-up and top-down interests, scientific and local knowledge and stakeholders through a range of courses, research projects and outreach activities at community and government levels involved with climate VIA. Emphasis is given to the concept "From knowledge into taking action" useful in DRR (Gaillard and Mercer, 2013).

Studies by Bravo *et al.* (2010) and Villamizar *et al.* (2016) are the supporting literature.

4.3 Climate EcoHealth (Clim-EcoHealth) and Vulnerability Index (CEHV-I), UCCLIMAS, UMSA, La Paz, Bolivia

The research and practice at UCCLIMAS focus on interdisciplinary ecosystem approach to health (EcoHealth) supported by the International Development Research Centre (Canada).

Emphasis is given to the development of integrated climate, ecosystem and socio-economic health vulnerability indicators (CEHV-I) in collaboration with CliVIA-Net.

The goal of Clim-EcoHealth is to build capacity to assess health vulnerability to climate change and variability based on interdisciplinary ESS knowledge, PoR and partnership. It seeks to develop and implement climate adaptation practice and policy. UCCLIMAS' EcoHealth approach focuses on the vulnerability dimensions of disease research. Climate change vulnerability (V) factors are exposure (E), sensitivity (S), the character and magnitude of climate change (CMC) and adaptive capacity (AC) (IPCC, 2007):

$$V : f(E;\ S;\ CMC;\ AC)$$

Disciplinary knowledge, e.g. entomology, epidemiology and climatology, are studied for a particular vulnerability study object (VCC_x) including a number of factors, which are analysed considering systemic thinking. The VCC framework (Figure 1) is "a process in motion", in which the character and magnitude of change between the past and current climate (Δ1), and the current and future climate (Δ2) is estimated from climate change scenarios. Each discipline contributes specific methodologies within the research process, furnishing constituent blocks important for health to build VCC_x (Aparicio-Effen *et al.*, 2016c).

The CEHV-I programme was developed to face the challenges posed by climate and ecosystem changes that will likely spread vector-borne diseases (Aparicio-Effen *et al.*, 2016a; IPCC, 2014). The index for "Chagas disease", a systemic infection transmitted to humans by *Triatoma infestans* at the endemic "Chaco" region in south-eastern Bolivia (Aparicio-Effen *et al.*, 2016a), is summarised in Box 3. It integrates ESS, IDR and Po for adaptation, sustainability, decision-making and policy, and might be modified for any climate-related disease, e.g. Dengue fever or Zika fever.

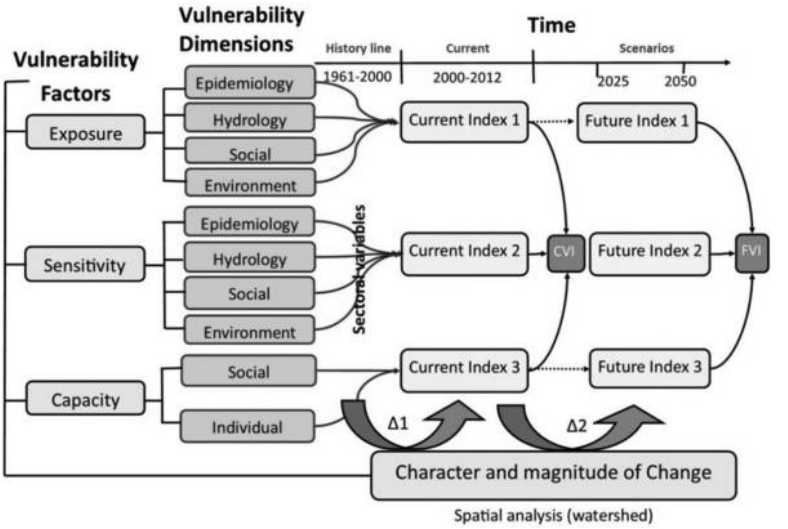


Figure 1.
Climate–ecosystem–health vulnerability indicators' assessment structure

Source: Aparicio-Effen *et al.* (2016c)

Box 3. Aggregated climate-health vulnerability index for Chagas disease

The Chagas disease health vulnerability index ($CCHV_I$) aggregates climate and non-climate indicators. The former represents the nature and magnitude of change through relationships between Δ1 and Δ2. The latter are divided into:

- Direct Health Vulnerability Index (DHV_I) which represents health sector performance (CO_I), e.g. health coverage and socio-economic indicators to assess the Adaptation Capacity Index (HCA_I).
- Indirect Health Vulnerability Index (IHV_I) which includes an epidemiological index (E_I) of infestation extent and other sectors index (OSI) of disease from climate change (Smith *et al.*, 2014), e. g. socio-economic shortcomings of households (UBN_I), ecosystem integrity (Herzog *et al.*, 2011) influence on diseases (IE_I), estimated from climatic indicators for 2005 and 2015.

Two exposure indexes are included:

(1) percentage of households with UBN_I; and
(2) human vulnerability index (HV_I) related to outbreaks of the disease.

The CCHVI aggregates both direct and indirect indices and the climate index expressed as follows:

$$CCHV_I = C_I\left((CO_I + (E_I + OSI)/AC_I \text{ or } C_I(\Sigma HDV + \Sigma HIV_I)/AC_I\right.$$

This climate health index is useful to implement adaptation actions and to identify the responsibility of policymakers and stakeholders. To calculate the "Future Index for 2025" ($CCHV_{I\text{-}2025}$), the same process is followed, including the outputs of the climate scenarios and Δ2 instead of Δ1.
The CCHV indicators and aggregated index can be applied to any disease or disaster, just changing the indicators to formulate climate VIA policies.

The building of $CCHV_I$ index was made through integrating ESS knowledge, systems analysis, natural and social disciplines through PoR and Po approaches focused on partnership with decision-makers and stakeholders, to face societal challenges, as suggested by Kueffer *et al.* (2012).

Studies by Aparicio-Effen *et al.* (2016a, 2016b, 2016c, 2017) and Nagy *et al.* (2016) are the supporting literature.

4.4 Via assessment in coastal areas of South America (SAVIA-Coast), USB, Venezuela and FC-UdelaR, Uruguay

Under the uncertainty of future climate change scenarios, adaptation in coastal areas will require new approaches to sustainable development that should be able to manage this complexity (Barbero and Tornquist, 2012; IPCC, 2013).

South America is vulnerable to climate change and variability which threaten its economy and sustainable development. At least 6 per cent of the population lives in low-elevation coastal zones (LECZ) exposed to SLR, ENSO-variability and storminess so that climate adaptation is a regional priority (Villamizar *et al.*, 2016).

The main challenge faced by SAVIA-Coast is the few successfully implemented adaptation measures in relation to the number of planned ones in the region. Despite the links between adaptation and sustainable development in Latin America (Metternicht, 2014), socio-economic development priorities other than climate change, SLR or storminess determine that public allocation of resources, awareness and efforts for coastal adaptation is less than optimal, leading to an adaptation deficit to current climate threats (Villamizar *et al.*, 2016).

The goal of SAVIA-Coast is to build capacity to develop VIA indicators that are useful in climate adaptation and DRR framed on the principles of sustainability linked with IDR, PoR and Po.

SAVIA-Coast develops graduate-level education and research focusing on:

- Education for sustainable development, climate change and DRR, as recommended by the United Nations (UNESCO, 2011; UN-DESD, 2014).
- Socio-economic and vulnerability indices.
- Socio-economic shared pathways – SSPs (O'Neill *et al.*, 2015).
- Links between CBA and sustainability because of the close climate–environment–development relationships (Ayers and Forsyth, 2009; UNESCO, 2016).

Studies by Nagy *et al.* (2014b) and Villamizar *et al.* (2016) are supporting literature.

4.5 Scenario planning (PSP), CliVIA-Net, FC-UdelaR, Uruguay, and USB, Venezuela

Because of the extensive uncertainties that exist in the future drivers of and responses to climate change, future scenarios are necessary to explore the potential consequences of different management response options (Moss *et al.*, 2010).

CliVIA-Net's PSP programme "Thinking of Futures" seeks to face the challenge "What if?" or how to manage uncertainty about the future. To answer this question, PoR and Po PSP approaches are followed (Cobb and Thompson, 2012; Moore *et al.*, 2013; NCA, 2013; Nagy *et al.*, 2014b). They aim at increasing buy-in to the scenarios with regard to "expected climates", and the adjustment of expectations to the institutional needs and implementation possibilities.

PSP is a strategic planning method to make flexible long-term plans (National Park Service, 2013). The primary purpose of PSP in climate assessment has been the application of information about the range of potential future conditions to identify robust options for development and management. Some benefits of a participatory approach are communication and a better understanding of uncertainties, consideration of local knowledge and perspectives and co-creation of scenarios that stretch thinking of scientists and decision-makers about adaptation options and needs (Noble *et al.*, 2014).

PSP mixes science-driven top-down and bottom-up approaches to build "alternative futures". The former includes ESS approach to integrate Earth's natural and socio-economic subsystems. This is achieved by means of using climate and environmental data, GCMs, Global Climate Representative Concentration Pathways – RCPs (IPCC, 2014) and SSPs outputs. In the latter, experts and stakeholders assess acceptability, barriers, plausible direction, magnitude and rate of change, impacts, thresholds and non-regret options to planning adaptation futures. An example of PSP is shown in Box 4.

Studies by Nagy *et al.* (2014a, 2016) and Nagy and Gutiérrez (2017) are supporting literature.

The International Congress on "Global Change and Climate Risks in Paraguay and the Rio de la Plata Basin" will be held in mid-2017 at FP-UNA, organised by the NGO "Guyra Paraguay" and the MCG Programme, with the participation of CliVIA-Net researchers.

5. Discussion

In the twenty-first century, higher education's role in social change is described predominantly in terms of its research functions and the potential for knowledge generation and transfer in support of innovation, following international standards. A further issue is the extent to which graduates need to be able to work across disciplinary and institutional boundaries, drawing on ways of thinking and ways of knowing bound in different disciplinary traditions (Brennan and

Box 4. Example of PSP developed for coastal areas of Uruguay

The key question before using PSP is: When/Why/For what to use scenario planning? When critical drivers cannot be controlled (Moore *et al.*, 2013). In virtue, adaptation evolves from an impact-based approach to a risk-based assessment (Chinvanno, 2011). SP is a valuable decision support method for integrating uncontrollable uncertainties into adaptation.

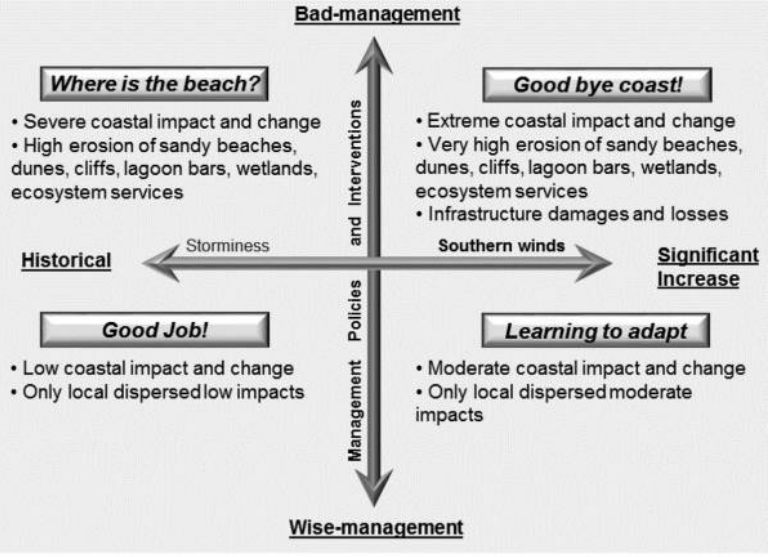
CliVIA-Net was invited to present PSP at the Brown International Advanced Research Institutes (BIARI) Climate 2016 (Brown University, USA, watson.brown.edu/biari/). An example developed for coastal areas of Uruguay was presented.

The methodological process consisted of four steps developed through group discussion including experts and stakeholders as follows:

(1) Identification of issues, stakeholders, factors, assumptions, climate and socio-economic driving forces.
(2) Identification of critical questions and uncertainties (How can we adapt to an uncertain future?" How long ahead are we looking into the future? How reliable are past trends and for how long are they robust? How reliable are climate models?
(3) Development of a few credible and logic scenarios based on "what if": A set of plausible environmental conditions for 2030-50.
(4) Discussion of implications and paths (storylines).

The main issue selected by experts and stakeholders was coastal erosion. The three topmost drivers of change were: storminess (wind-induced flooding), management policies and interventions and SLR, whereas the main critical uncertainties were management practices and policies (Nagy and Gutiérrez, 2017).

Scenario logics are presented as a "2 × 2 matrix framework" where driving forces and characteristics are plotted and described (Harbottle, 2013). Figure 2 shows the scenario logic developed for a hypothetical Uruguayan coastal area for 2050.



Source: Modified from Nagy and Gutiérrez, (2017)

Figure 2.
Hypothetical four-scenario logic (2 × 2 matrix) combining two topmost drivers "storminess vs management policies and interventions" in coastal areas of Uruguay for 2050

Shah, 2011). It is increasingly accepted that the link between producing and applying knowledge needs to be more direct; indeed, many scientists and policymakers have called for more interdisciplinarity, more partnerships and better problem orientation (Kueffer *et al.*, 2012).

Following the HE trends presented previously (Stephens *et al.*, 2008; Barth, 2015), the CliVIA-Net has emerged as an agent for climate VIA (e.g. well-being and health, coastal areas, flooding). The focus of the network on adaptation is evidenced by the following paragraph:

> Adaptation to climate change has gained a prominent place on global, national, and local policy agendas over the last decade, evolving from mainly climate risks impacts and vulnerability assessments to mainly adaptation action (Swart *et al.*, 2014; Wise *et al.*, 2014).

The adaptation actions seek to relate climate change and environmentally sustainable development pathways within the context of multiple stressors and vulnerabilities, and with concern for both intra- and intergenerational equity (Brown, 2011). In this regard, Vilches and Gil (2016) states:

> To make the transition to sustainability it is necessary to incorporate in research and decision-making persons whose usual work is developed outside academia, as the objectives, knowledge and intervention ability of citizens are essential to define and implement viable strategies.

The programmes Master of Science in Global Change (MGC), Cátedra Libre (CLCC), Climate EcoHealth, CEHV-I and SAVIA-Coast are designed based on interdisciplinary ESS education, practice-oriented research and problem orientation. Emphasis is put on influencing decision-making with regard to climate-related societal challenges which are already threatening or impacting ecosystem services, integrity and sustainability, as well as the population's well-being and health.

Community and government stakeholders' participation is a key element of PoR and Po adaptation planning experiences, e.g. EcoHealth (Aparicio-Effen *et al.*, 2016a) and CBA (Villamizar *et al.*, 2016). Participation is deemed to be important for the co-production of knowledge, planning and management and because ultimately community "buy-in" and support from those affected will be required to succeed (Kueffer *et al.*, 2012; Mimura *et al.*, 2014). The network integrates top-down and bottom-up approaches at programmes CLCC, Clim-EcoHealth, CEHV-I, SAVIA-Coast and Thinking of Futures (PSP).

Three strategies are followed to meet societal challenges to sustainability, namely, interdisciplinary research teams, research partnerships and framing research questions that are aimed at solving specific problems as stated by Kueffer *et al.* (2012).

Emphasis is given to IDR, PoR and Po to develop climate, environmental, human and socio-economic vulnerability indicators aggregated into flexible indexes as shown in Clim-EcoHealth and CEHV-I. These indicators are useful as a management tool to design public policies and strengthen the adaptive capacity of communities and local governments, as well as the complex relationships between socio-economic development, management decisions and impacts (Aparicio-Effen *et al.*, 2016a, 2017; Villamizar *et al.*, 2016).

The main challenge faced by CLiVIA-Net to develop adaptation activities is influencing decision-making. Interdisciplinarity and stakeholders' participation toward the co-creation of knowledge and solutions have been achieved by all groups. An example of a successful IDR and systems thinking to face societal challenges are the index developed by Clim-EcoHealth and CEHV-I.

Another focus of CliVIA-Net is to adapt shared socio-economic scenarios originally developed for large regions to the local scale. This objective is developed at the USB, Venezuela, in collaboration with FC-Udelar, Uruguay (SAVIA-Coast).

The programme PSP was developed by the network at FC-Udelar receiving inputs from MGC, Clim-EcoHealth, CEHV-I and SAVIA-Coast. For instance, SAVIA-Coast has already produced research and publications (Nagy *et al.*, 2014a; Nagy and Gutiérrez, 2017) showing the integration of disciplinary and local knowledge to thinking of futures aimed at supporting coastal adaptation decisions.

The shift from a disciplinary-based teaching to an interdisciplinary problem-oriented teaching and research has presented higher education with the challenge of having to "go out" of universities to "pay attention to" the emerging socio-environmental problems related to adaptation practice. This is the case for CLCC, Clim-EcoHealth, CEHV-I, SAVIA-Coast and PSP, dealing with landslides and vector-borne diseases (Aparicio-Effen *et al.*, 2016a, 2016b, 2017; Nagy *et al.*, 2016), coastal flooding or bad management practices (Aparicio-Effen *et al.*, 2016b; Nagy and Gutiérrez, 2017).

While these changes at the educational and research levels have already been part of the international framework for a few decades (Barth, 2015; SARUA, 2010), it has been challenging so far to include these trends in Bolivia, Paraguay, Uruguay and Venezuela, probably due to local education backgrounds.

The originality of CliVIA-Net lies in:

- building on the basic approaches already incorporated at "Cátedra Libre", the Climate Change and Environmental Health Unit and the MGC (e.g. interdisciplinarity), to integrate all of them into a collaborative network; and
- evolving from interdisciplinary education into practice-oriented research and problem orientation practice (e.g. CBA and EcoHealth).

The science of/for adaptation is well suited to the overall goal and specific activities of the network owing to its originality, comprehensiveness, literature cited and disciplinary changes. Consequently, it became the "leading idea" of the network.

The concepts mobilised through CliVIA-Net programmes could be synthesised as follows:

> CliVIA-Net education, research, and practice build on the process of answering questions to face the challenges posed by emergent climate-related environmental, health and social problems whose solutions are beyond the scope of an area of research expertise. It is based on earth system science and participatory research involving actors from inside and outside academia conducive to co-produce assessments and plans with the ultimate objective of developing environmentally sustainable solutions.

The International Congress on "Adaptation to Global Change and Climate Risks" held in the Facultad Politécnica, Asunción, Paraguay, in 2017, is a milestone for the development of the network and for creating new alliances.

6. Conclusions

The purpose of this article was to present the Climate Vulnerability, Impact and Adaptation (CliVIA) Network, a university-based collaborative education, research and practice effort on climate change and variability adaptation in Bolivia, Paraguay, Uruguay and Venezuela.

The network builds on a framework of foundation concepts such as Earth System Science basic knowledge, cross-disciplinary language, practice-oriented research and problem-oriented practice approaches, e.g. community-based adaptation and EcoHealth.

The main challenges faced to develop CliVIA-Net are to achieve interdisciplinarity, integrate stakeholders, co-produce knowledge and solutions and influence decision-making in adaptation.

The first three have been successfully achieved by all groups, while the fourth has been yet achieved by Clim-EcoHealth, CEHV-I, and CLCC. The programmes SAVIA-Coast and "Thinking of Futures" are profiting from the experience of the network and have focused on research and education.

The main results are expressed in terms of solution-based approaches from the academy to a set of regional cases which have in common similar threats and challenges addressed to give common solutions.

The foundation concepts and approaches were mobilised at each case study through:

- Connecting basic disciplinary knowledge and interdisciplinary education with practice research to solving climate-related societal challenges (e.g. EcoHealth).
- Focusing on PoR and Po CBA and EcoHealth approaches to face emergent climate-related socio-environmental problems, e.g. vector-borne diseases; coastal flooding and sea-level rise (e.g. CEVH-I; PSP).
- Co-producing knowledge and solutions with experts and stakeholders in PoR and Po approaches, e.g. EcoHealth, which is already influencing decision-making (e.g. aggregated Chagas Vulnerability Index).

Despite the worldwide trend to develop adaptation programmes, it remains a challenge in the four countries involved in the network. CliVIA-Net intervenes as an alternative to this trend in the higher education systems. This experience suggests that higher education institutional learning is an important component of effective adaptation to climate change and variability.

The value of CliVIA-Net is successful in integrating "from knowledge into action" based on interdisciplinary graduate education, partnership, participatory research and problem-oriented action. Currently, the network is moving forward towards "reaching a science for/of adaptation" at research and practice, by developing scientific production, conferences and a proven influence on decision-making.

References

Altbach, P.G., Reisberg, L. and Rumbley, L.E. (2009), "Trends in global higher education: tracking an academic revolution", *UNESCO 2009 World Conference on Higher Education*, United Nations Educational, Scientific and Cultural Organization, Paris, p. 246, available at www.uis.unesco.org/Library/Documents/trends-global-higher-education-2009-world-conference-en.pdf (accessed January 2016).

Aparicio-Effen, M., Arana, I., Aparicio, J. and Ocampo, M. (2016c), "Adaptación al cambio climático: sector salud de la América Latina, estudio de caso y metodología de formulación de indicadores", paper presented at the "Congreso Internacional de Medicina de la Altura", February22-26, 2016, La Paz, Bolivia, available at: www.colegiomedicodebolivia.org.bo/index.php/154-congresointernacional-de-medicina-de-altura-c-i-m-a.

Aparicio-Effen, M., Arana, I., Aparicio, J., Ramallo, C., Bernal, N., Nagy, G.J. and Ocampo, M. (2016a), "Climate change and variability health vulnerability in Bolivian Chaco ecosystems", in Leal Filho, S., Azeiteiro, U. and Alvez, F. (Eds), *Climate Change and Health: Improving Resilience and Reducing Risks*, Climate Change Management Series, Springer-Verlag, Heidelberg, doi:10.1007/978-3-319-24660-4_14.

Aparicio-Effen, M., Arana, I., Aparicio, J., Cortez, P., Coronel, G., Pastén, M., Nagy, G.J., Galeano Rojas, A., Flores, L. and Bidegain, M. (2016b), "Introducing hydroclimatic extremes and human impacts in Bolivia, Paraguay and Uruguay", in Leal Filho, W., Azeiteiro, U. and Alvez, F. (Eds), *Climate Change and Health: Improving Resilience and Reducing Risks*, Climate Change Management Series, Springer-Verlag, Heidelberg, doi: 10.1007/978-3-319-24660-4_26.

Ayers, J. and Doldman, D. (2010), "Climate change adaptation and development I: the state of the debate", *Progress in Development Studies*, Vol. 10 No. 2, pp. 161-168.

Ayers, J. and Forsyth, T. (2009), "Community-based adaptation to climate change: strengthening resilience through", *Development, Environment*, Vol. 51 No. 4, pp. 22-31.

Barbero, J.A. and Tornquist, R.R. (2012), "Transporte y cambio climático: hacia un desarrollo sostenible y de bajo carbono", *Revista Transporte y Territorio*, Vol. 6, pp. 8-26.

Barth, M. (2015), *Implementing Sustainability In Higher Education: Learning in an Age of Transformation*, Routledge, Taylor and Francis, New York, NY, p. 222.

Bravo, L., Hernández, R.J., Llatas, I. and Salcedo, A. (2010), "Desarrollo de un sistema de alerta temprana comunitario en el Estado Vargas", *Revista Temas De Coyuntura*, Vol. 61, pp. 169-178.

Brennan, J. and Shah, T. (2011), *Higher Education and Society in Changing Times: Looking Back and Looking Forward*, Brennan, J. and Shah, T. (Eds), Center for Higher Education and Information (CHERI), The Open University, London, p. 90, available at: www.open.ac.uk/cheri/documents/Lookingbackandlookingforward.pdf (accessed April 2016).

Brown, K. (2011), "Sustainable adaptation: an oxymoron?", *Climate and Development*, Vol. 3 No. 1, pp. 21-31, doi:10.3763/cdev.2010.0062.

Charron, D.F. (2012), "Ecosystem approaches to health for a global sustainability agenda", *Ecohealth*, Vol. 9 No. 3, pp. 256-266, doi:10.1007/s10393-012-0791-5.

Chinvanno, S. (2011), "Mainstreaming climate change into community development strategy: a critical opinion on climate change adaptation planning and case study in Thailand", available at: www.thailandadaptation.net/pdf/pdf3/14.pdf, Bangkok (accessed June 2016).

Cobb, A.N. and Thompson, J.L. (2012), "Climate change scenario planning: a model for the integration of science and management in environmental decision-making", *Environmental Modelling and Software*, Vol. 38, pp. 296-305, doi:10.1016/j.envsoft.2012.06.012.

Coronel, G., Pastén, M., Báez, J., Monte Domecq, R., Bidegain, M. and Nagy, G.J. (2015), "Improving capacities and communication on climate threats for water resources adaptation in Paraguay", in Leal Filho, W. (Ed), *Handbook of Climate Change Adaptation*, Climate Change Management Series, Springer-Verlag, Springer-Verlag, Berlin, Heidelberg, pp. 1091-1108, ISBN: 978-3-642-38669-5, doi:10.1007/978-3-642-40455-9_113-1.2015.

EcoHealth (2014), "EcoHealth 2014 call to action EcoHealth and climate change: connections for health, ecosystems, and society", Inbiose and Co-PEH, UQAM, available at: www.ecohealth-live.net (accessed March 2015).

Ferrara de Giner, G., Martelo, M.T., Lairet, R., Villamizar, A. and Sánchez, J.C. (2012), "Una propuesta de sensibilización y capacitación de comunidades para la adaptación al Cambio climático: caso Parroquia San Pedro, Caracas, Venezuela", *e-annals, ABES-AIDIS, XXXIII Congresso Interamericano de Engenharia Sanitária e Ambiental (Associação Brasileira de Engenharia Sanitária e Ambiental), Salvador, Bahia*,Teme VIII-024, pp. 1-7.

Gaillard, J.C. and Mercer, J. (2013), "From knowledge to action: bridging gaps in disaster risk reduction", *Prog Hum Geogr*, Vol. 37 No. 1, pp. 93-114.

Grossfeld, K., Lohmann, G., Wolf-Gladrow, D., Ladstätter-Weißenmayer, A., Notholt, J., Unnithan, V. and Wegener, A. (2013), "The structural and educational concept in an interdisciplinary research school for earth system sciences", in Lohmann, G., Grossfeld, K., Wolf-Gladrow, D., Unnithan, V., Notholt, J. and Wegener, A. (Eds), *Earth System Science: Bridging The Gaps Between Disciplines: Perspectives from a Multi-disciplinary Helmholtz Research School*, Springer Briefs in Earth System Sciences, Springer International Publishing, Switzerland, pp. 3-8, doi:10.1007/978-3-642-32235-8.

Harbottle, T. (2013), "Effective planning and risk management in an uncertain business environment", Risk management and scenario planning, University of Lethbridge, available at: www.pptdirectory.com/preview.php?key=Effective, Planning & Risk Management in an Uncertain

Business, available at: http://classes.uleth.ca/200603/mgt4451y/U%20of%20L%20Mgt%204451%20Risk%20and%20ScenariosPresentation.ppt. (accessed June 2016).

Herzog, S.K., Martínez, R., Jorgensen, P.M. and Tiessen, H. (2011), *Climate Change and Biodiversity in the Tropical Andes*, Inter-American institute for Global Change Research (IAI) and Scientific Committee on Problems of the Environment (SCOPE), UNESCO, Paris, p. 348, ISBN: 978-85-99875-05-6.

IPCC (2007), "Climate change 2007: impacts, adaptation and vulnerability", in Parry, M., Canziani, O., Palutikoff, J., van der Linden, P. and Hanson, C. (Eds), *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, University Press, Cambridge, Cambridge, p. 976.

IPCC (2013), "Summary for policymakers", in Stocker, T.F., Qin, D., Plattner, G.K., Tignor, M., Allen, S. K., Boschung, J. and Midgley, P.M. (Eds), *Climate change 2013: The physical science basis, Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change*, Cambridge University Press, Cambridge, p. 29.

IPCC (2014), "Climate change 2014: impacts, adaptation, and vulnerability", in Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R. and White, L.L. (Eds), *Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate*, Cambridge University Press, Cambridge and New York, NY, pp. 1-32.

Klein, J. and Newell, W. (1998), "Advancing interdisciplinary studies", in Newell W. (Ed.), *Interdisciplinarity: Essays from the literature*, College Board, New York, NY, pp. 3-22.

Kueffer, C. and Hirsch Hadorn, G. (2008), "How to achieve effectiveness in problem-oriented landscape research: the example of research on biotic invasions", *Living Reviews in Landscape Research*, Vol. 2 No. 2, available at: www.livingreviews.org/lrlr-2008-2, doi:10.12942/lrlr-2008-2

Kueffer, C., Underwood, E., Hirsch Hadorn, G., Holderegger, R., Lehning, M., Pohl, C., Schirmer, M., Schwarzenbach, R., Stauffacher, M., Wuelser, G. and Edwards, P. (2012), "Enabling effective problem-oriented research for sustainable development", *Ecology and Society*, Vol. 17 No. 4, p. 8, available at: http://dx.doi.org/10.5751/ES-05045-170408

Marshall, E.A. (2010), "Practice-Oriented Research", in Mills, A.J., Durepos, G. and Wiebe, E. (Eds), *Encyclopedia of Case Study Research*, SAGE Publications, Thousand Oaks, pp. 723-724, doi:10.4135/9781412957397.n266, http://dx.doi.org/10.4135/9781412957397.n266

Metternicht, G. (2014), "Climate change vulnerability, impact, and adaptation: Assessment lessons from Latin America", *International Journal of Climate Change Strategies and Management*, Vol. 6 No. 4, pp. 442-476, doi:10.1108/IJCCSM-06-2013-0076.

Mimura, M., Pulwarty, R., Duc, D.M., Elshinnawy, I., Hiza Redsteer, M., Huang, H.Q., Ndinkem, J. and Sanchez Rodriguez, R.A. (2014), "Adaptation planning and implementation", in Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P. R. and White, L.L. (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 and New York, NY, pp. 869-898.

Moore, S.S., Seavy, N.E. and Gerhart, M. (2013), "Scenario planning for climate change adaptation: a guidance for resource managers", Point Blue Conservation Science and California Coastal Conservancy, Petaluma, CA, p. 61, available at: http://scc.ca.gov/files/2013/07/Scen-planning_17july2013_FINAL-3.pdf (accessed July 2014).

Moss, R.H., Edmonds, J.A., Hibbard, K.A., Manning, M.R., Rose, S.K., van Vuuren, D.P., Carter, T.R., Emori, S., Kainuma, M., Kram, T., Meehl, G.A., Mitchell, J.F.B., Nakicenovic, N., Riahi, K., Smith, S.J., Stouffer, R.J., Thomson, A.M., Weyant, J.P. and Wilbanks, T.J. (2010), "The next generation

of scenarios for climate change research and assessment", *Nature*, Vol. 463, pp. 747-756, doi:10.1038/nature08823.

Nagy, G.J. and Gutiérrez, O. (2017), "Participatory scenario planning to address climate threats, impacts, and adaptation in socio-environmental systems, climate change adaptation in Latin America: managing vulnerability, fostering resilience", *Climate Change Management Series*, Springer-Verlag, Heidelberg.

Nagy, G.J., Seijo, L., Bidegain, M. and Verocai, J.E. (2014b), "Stakeholders' climate perception and adaptation in coastal Uruguay", *Journal of Climate Change and Strategies Management, Lay Rationalities of Climate Change*, Vol. 6, pp. 63-84, doi:10.1108/IJCCSM-03-2013-0035.

Nagy, G.J., Muñoz, N., Verocai, J.E., Bidegain, M. and Seijo, L. (2014a), "Adjusting to current climate threats and planning adaptation: the case of the Uruguayan coastal zone within the Rio De La Plata river estuary", *Journal of Integrated Coastal Management*, Vol. 14, pp. 1-15, doi:10.5894/rgci472.

Nagy, G.J., Coronel, G., Pastén, M., Báez, J., Monte Domecq, R., Galeano Rojas, A., Flores, L., Ciganda, C., Bidegain, M., Aparicio-Effen, M., Arana, I. and Aparicio, J. (2016), "Impacts on well-being and health of excessive rainfall and floods in Paraguay, Uruguay and Bolivia", in Leal Filho, W., Azeiteiro, U. and Alvez, F. (Eds), *Climate Change and Health: Improving Resilience and Reducing Risks*, Climate Change Management Series, Springer-Verlag, Heidelberg, doi:10.1007/978-3-319-24660-4.

National Academies (2003), *Bio 2010: Transforming Undergraduate Education for Future Research Biologists*, National Academies Press, Washington, DC, p. 208, doi:10.17226/10497.

National Park Service (2013), "Using scenarios to explore climate change: a handbook for practitioners", National Park Service Climate Change Response Program, Fort Collins, CO, available at: www.nps.gov/subjects/climatechange/upload/CCScenariosHandbookJuly2013.pdf.

NCA (2013), "Scenarios for climate assessment and adaptation: participatory scenario planning", NCA – National Climate Assessments-United States Global Change Research Program, available at: http://scenarios.globalchange.gov/accouncement/17.pdf (accessed July 2014).

Noble, I.R., Huq, S., Anokhin, Y.A., Carmin, J., Goudou, D., Lansigan, F.P., Osman-Elasha, B. and Villamizar, A. (2014), "Adaptation needs and options", in Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L. Estrada, Y.L., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R. and White, L.L. (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 and New York, NY, USA, pp. 833-868.

O'Neill, B.C., Kriegler, E., Ebi, K.L., Kemp-Benedict, E., Riahi, K., Rothman, D.S., van Ruijven, B.J., van Vuuren, D.P., Birkmann, J., Kok, K., Levy, M. and Solecki, W. (2015), "The roads ahead: narratives for shared socioeconomic pathways describing world futures in the 21st century", *Global Environmental Change*, Elsevier, The Netherlands, Published online on 12 February 2015, doi:10.1016/j.gloenvcha.2015.01.004.

Rieckmann, M. (2012), "Future-oriented higher education: which key competencies should be fostered through university teaching and learning?", *Futures*, Vol. 44 No. 2, pp. 127-135.

Ruzek, M. (2007), "Earth system science education: a perspective from the NASA/USRA college and university earth system science education for the 21st century program (ESSE 21)", Universities Space Research Association (USRA), available at: www.qem.org/NASA-SFConfPresentations/%20Thurs%20130/ruzek22feb07reva.ppt.pdf.

SARUA (2010), *Climate Change, Adaptation and Higher Education: Securing Our Future*, Sarua leadership dialogue series, South African Regional Universities Association, Vol. 2 No. 4, pp. 144, available at: www.sarua.org (accessed April 2016).

Second Nature (2011), "Higher Education's role in adapting to a changing climate", Presidents' Climate Commitment American College & University Higher Education's Role in Adapting to a

Changing Climate, A publication of the Second Nature Education for Sustainability, p. 33, available at: www.presidentsclimatecommitment.org (accessed April 2016).

Smith, K., Woodward, A., Campbell-Lendrum, D., Chadee, D., Honda, Y., Liu, Q., Olwoch, J.M., Revich, B. and Sauerborn, R. (2014), "Human health: impacts, adaptation, and co-benefits", in Field, C.B., Barros, V. and Dokken, D. (Eds), *Climate Change 2014: Impacts, Adaptation, and Vulnerability, Vol I: 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, pp. 709-754.

Stephens, J.C., Hernandez, M.E., Roman, M., Graham, A.C. and Scholz, R.W. (2008), "Higher education as a change agent for sustainability in different cultures and contexts", *International Journal of Sustainability in Higher Education*, Vol. 9 No. 3, pp. 317-338.

Swart, R., Biesbroek, R. and Lourenço, T.C. (2014), "Science of adaptation to climate change and science for adaptation", *Frontiers in Environmental Science*, Vol. 2 No. 9, pp. 1-8, doi:10.3389/fenvs.2014.00029.

UKCIP (2014), "United Kingdom climate impact programme", *Glossary*, available at: www.ukcip.org.uk/glossary/ (accessed July 2016).

UN-DESD (2014), "Decade of education for sustainable development 2005–2014 (DESD)", available at: http://en.unesco.org/themes/education-sustainable-development/what-is-esd/un-decade-of-esd (accessed April 2016).

UNEP (2012), "Climate change strategy", UNEP Programme of Work 2010-2012, UN 2012, COP 18, available at: http://unfccc.int/meetings/doha_nov_2012/meeting/6815/php/view/documents.php (accessed April 2016).

UNESCO (2011), "Educación para el desarrollo sostenible, examen por los expertos y de los procesos y el aprendizaje", UNESCO, Paris, p. 141, available at: unesdoc.unesco.org/images/0019/001914/191442s.pdf (accessed April 2016).

UNESCO (2016), "Education for sustainable development: climate change education for sustainable development at UNESCO", p. 19, available at: www.unesco.org/new/en/education/themes/leading-the-international-agenda/education-for-sustainable-development/climate-change-education/ (accessed April 2016).

Vilches, A. and Gil, D. (2016), "La ciencia de la sostenibilidad: una necesaria revolución científica?", *Revista Iberoamericana de Educación/Revista Ibero-americana de Educação*, Vol. 69, pp. 39-60.

Villamizar, A., Gutiérrez, M.E., Nagy, G.J., Caffera, R.M. and Leal Filho, W. (2016), "Climate adaptation in coastal areas of South America: current trends and case studies from Venezuela and Uruguay", *Journal of Climate and Development*, doi:10.1080/17565529.2016.1146120.

Wise, M., Fazey, I., Stafford Smith, M., Park, S.E., Eakin, H.C., Archer Van Garderen, E.R.M. and Campbell, B. (2014), "Reconceptualising adaptation to climate change as part of pathways of change and responses", *Global Environmental Change*, Vol. 28, pp. 325-336, available at: http://dx. doi.org/10.1016/j.gloenvcha.2013.12.002

World Commission on Environment and Development (1987), "Our common future", available at: www.un-documents.net/our-common-future.pdf

Further reading

Aparicio-Effen, M., Arana-Pardo, I., Aparicio, J., Ocampo, M., Roque, S. and Nagy, G.J. (2017), "A successful early warning system for hydroclimatic extreme events: the case of La Paz city mega landslide", *Climate Change Adaptation in Latin America: Managing Vulnerability, Fostering Resilience*, Climate Change Management Series, Springer-Verlag, Heidelberg.

UNDP (2015), "Sustainable development goals: introducing the 2030 agenda for sustainable development", available at: https://sustainabledevelopment.un.org/post2015/transformingourworld (accessed April 2016).

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