Mapping Adaptation Opportunities and Activities in an Interactive Atlas

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Abstract The need for transparency is taking more prominence in international climate negotiations as developed countries pledge large sums of money to foster adaptation efforts in developing countries. Tools that provide accurate and up-to-date spatial information that can be easily used and vetted by local practitioners may provide effective and affordable ways to improve transparency. The Global Adaptation Atlas is such a tool, combining vetted, publicly available climate impact data with timely maps of on the ground adaptation projects to highlight confluences of effects of climate change with actions taken to address those effects. Here, we describe the structure and general functions of the Global Adaptation Atlas and explain how it may be utilized to track short-term investments in adaptation. Over longer time scales, it may also help gauge the effectiveness of specific adaptation investments as well as reveal how different climate impacts affect long-term investment in differing regions.

Keywords Adaptation · Climate finance · Climate impacts · Development · Transparency · Geographic information systems

INTRODUCTION: PROBLEMS AND SOLUTIONS

Effectively adapting to a changing climate represents one of the most formidable challenges facing the international community over the next century. The stated goal of global average temperature increases less than 2°C as established in the Conferences of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) is growing more and more difficult to achieve. Concurrently, predicted changes in natural systems are occurring on faster timescales than originally anticipated

and greenhouse gases emissions continue to increase at rates once labeled “worst-case.” After nearly 20 years of international negotiations, the international community is still a great distance from agreeing to a comprehensive system for reducing emissions. As a result of all these dynamics, adaptation has grown in prominence over the past few years and will continue to play a large role on the international stage.

Adapting to the many impacts that will manifest from the changing climate is a vast challenge because it is so complex and affects so many different aspects of human society. Increasing average temperatures and shifting precipitation patterns will drive processes that lead to more extreme storms, droughts, floods, sea level rise, shortened winters and earlier pollination schedules, altered disease and pest distributions, and major changes in terrestrial and marine ecosystems. Effects on natural systems in turn affect human systems like water availability, agriculture, public health, and economic development. The goal of adaptation responses should be to increase the resilience of human societies to respond to climate stressors to food, water, land, health, and livelihoods. The international community is mobilizing to assist those most vulnerable to these impacts with large influxes of money to build resilience.

Adaptation policy design is, among other things, a spatial problem; the locations of people, resources, and climate impacts are central to making decisions about adaptive responses. Responding to the multiple issues posed by adaptation require a coordination mechanism that brings together information on the impacts of climate change, adaptation activities, and financial disbursements from donors for aiding such activities. The Global Adaptation Atlas is designed to be one such coordinator of information and to serve as a tracking mechanism that

collates diverse information on the peer-reviewed literature on the human impacts of climate change and details on adaptation activities, including information on sources of funding. In this article, we describe the current status of adaptation internationally and why response efforts should include tools like the Adaptation Atlas. We then present the architecture and function of the Atlas.

THE NEED FOR INTERNATIONAL ADAPTATION

As scientists work to better understand the scale and magnitude of future climate impacts, academics, NGOs, and other actors are making more explicit connections between those impacts and their effects on human populations. Actions to reduce the vulnerability of communities to adverse impacts and to increase the resilience of social, economic, and environmental systems form the core of adaptation efforts moving forward. As these activities progress, they will likely be designed to be harmonious with issues of sustainable development, as the links between adaptation and development have been noted by prominent scholars for years (Brown and Kaur 2009), and major institutions like the World Bank recognize the potential negative impacts of climate change to ongoing development issues (Agrawal 2008).

While adaptation will likely occur everywhere, developing countries may suffer the most negative impacts while possessing the least number of resources to effectively respond. Impacts will manifest across multiple areas critical to human survival and development, including food production, access to water and arable land, public health, and economic viability. In regards to food production, climate models project changes in food crop yields will have a much more deleterious effect on developing countries than developed countries (Parry et al. 2004). On the public health front, distributions of malaria may increase in some African countries (Tanser et al. 2003) and the geographic extent of dengue fever may expand significantly (Hales et al. 2002). Instream water flows may decrease in southern Africa, southern Europe, and the Middle East (Milly et al. 2005), which will likely have significant health and economic consequences. These potential impacts will have to be considered when designing and executing development plans in poor and rich countries alike, though the ability to do so will be dependent on the types of impacts expected.

Adaptation efforts will need to be tailored to local conditions and needs because climatic impacts vary geographically in magnitude and type. Thus, policies and actions will take different forms across landscapes based on the resources available in different areas, the ability of communities to respond effectively, and the nature of impacts. As nations gear up to adapt, they will need to

harness ideas and tools and explicitly consider the geographic heterogeneity of climate change.

STATUS OF CURRENT INTERNATIONAL ADAPTATION EFFORTS

The status of adaptation in international negotiations has grown significantly over the past decade to where it is now seen as one of the key aspects of any future accord. Within the UNFCCC, the focus on adaptation first developed in two forms: a concentrated program to understand the important scientific and socio-economic factors and an effort to improve methodologies for executing on-the-ground adaptive actions.¹ The urgency for strong action spurred by the fourth IPCC report led to adaptation's inclusion as one of the four building blocks for a post-2012 climate regime established at COP 13 with the Bali Road Map in 2007.²

The Copenhagen Accord 2 years later solidified support for adaptation action in vulnerable areas by developed countries, which agreed in the Accord not only to generate “adequate, predictable, and sustainable financial resources, technology, and capacity-building”³ for implementing adaptation actions but also pledged USD 30 billion in fast-start financing to be split between mitigation and adaptation efforts from 2010 to 2012. As part of the package of agreements from COP 16 the following year, the Cancun Adaptation Framework established an Adaptation Committee to help implementation of robust adaptation actions with technical support and information sharing. In addition, the framework encouraged nations to augment current efforts through national adaptation planning efforts and to buffer resilient systems. It also established the Green Climate Fund, which will be used to support actions in thematic areas, including adaptation.

To jumpstart the most vulnerable nations in preparing for potentially damaging climate impacts and receiving aid from wealthier nations, the UNFCCC also requested Least Developed Countries (LDCs) to develop National Adaptation Plans of Actions (NAPAs). As of November 2010, 38 countries had submitted their NAPAs to the UNFCCC for potential funding. These formal plans lay out the important needs specific to each nation, impacts that are most urgent or will cost the most if unaddressed and what

¹ Under UNFCCC structures, scientific efforts, called the “Nairobi Work Programme,” were placed under the Subsidiary Body for Scientific and Technological Advance (SBSTA) and improving methodologies fell under the Subsidiary Body for Implementation (SBI).

² Decision 1/CP.13. Bali Action Plan. 2007. Retrieved November 23, 2011 from <http://unfccc.int/resource/docs/2007/cop13/eng/06a01.pdf>.

³ Draft decision -/CP.15. 2009. Retrieved June 20, 2011 from <http://unfccc.int/resource/docs/2009/cop15/eng/107.pdf>.

measures are best-suited to address them, and the government's approach to implementing those necessary actions. NAPAs serve a number of critical purposes, not least of which is showing how LDCs intend to use the financial resources they will receive from developed countries. Furthermore, they must identify efforts that are actionable with existing information to reduce delays and move funds to where they are needed.

As official actions on adaptation have grown, so has the structure to provide them with appropriate funds to turn plans into on-the-ground results. Development agencies of Annex I parties under the UNFCCC parties have already committed to and are supporting various adaptation activities, including the development of NAPAs,⁴ vital scoping and assessment activities, and implementation of much-needed programs and projects. The Adaptation Fund, supported through a 2% levy on proceeds from the Clean Development Mechanism established under the Kyoto Protocol, is now functional and currently funding existing adaptation efforts. Moreover, along with the fast-start financing promised in Copenhagen, developed nations have also pledged as part of the agreement to establish a fund that will divvy out USD 100 billion annually start in 2020 to developing countries threatened with severe climate change impacts.

In addition to the plethora of funds to be made available under the auspices of the UNFCCC; bilateral, multilateral, philanthropic, and private actors play a key role in the adaptation finance puzzle. In particular, multilateral donors such as the World Bank and UN Development Program (UNDP) have established multiple programmatic endeavors targeted at furthering adaptation efforts, including the Pilot Program for Climate Resilience (established by the World Bank in 2009), and the Small Grants Programme (established by UNDP in 2010). Other regional multilateral banks such as the African Development Bank (AfDB), the Inter-American Development Bank (IDB), the Asian Development Bank (ADB), and the European Bank for Reconstruction and Development (EBRD), as well as to other inter-governmental organizations such as the International Finance Corporation and United Nations for Environment Programme (UNEP), play vital roles in their regions and areas of interest. Philanthropic organizations such as the Rockefeller Foundation,⁵ are devoting

significant resources toward the adaptation field. Activities of these diverse donors and actors need to be coordinated on a global, regional, national, and local level so as to avoid duplication of efforts or maladaptive strategies, and to leverage commonalities and possibilities for co-benefits in their approaches.

TRANSPARENCY AND INFORMATION NEEDS

As developed countries and NGOs steer more resources toward international adaptation efforts, they will likely seek some level of assurance that funds and efforts are truly getting to those who need aid most and projects are being implemented as effectively as possible. Transparency is a necessity for ensuring the efficacy of adaptation support (Muller 2008; Barr et al. 2010), both in the distribution of funds and the support of specific projects with those funds. Indeed, the level of participation of developed countries like the United States in adaptation funding may in part depend on the levels of transparency throughout the funding chain. As a result, funders will need to utilize tools and techniques that can help keep track of who is distributing and receiving adaptation funds, what those funds are intended to support, and how long they are intended to last.

Ensuring transparency along the fund distribution chain, however, will not alone ensure success for adaptation projects. The amount and quality of information that can be collected and provided to policymakers in a useful form about expected impacts from climate change will play a major role in determining the efficacy of adaptive responses. On-the-ground actors typically do not have the resources to conduct extensive studies on local climate impacts and must look for sources to help them understand the conditions they will likely face in the future. Useful climate information is in many ways a public good. That fact combined with the massive need to inform a wide swath of impact areas and different regions means that the responsibility to gather information and make it easily accessible often falls to national governments (Macauley 2010).

Unfortunately, LDCs and other vulnerable countries lack the requisite expertise and resources to gather and provide climate data or have yet to develop reliable systems to consistently provide and process information useful for making decisions (Govender 2010). Moreover, the sheer magnitude of climate impacts that will manifest in the developing world can be overwhelming such that it is difficult for data providers to recognize what information is most relevant or needed. Thus, it will be critical to get developing countries access to tools and systems that can present climate information in a digestible form, but are also flexible and responsive enough to address user-specific challenges and consider the heterogeneous nature of

⁴ The LDCs Fund, operated by the Global Environmental Facility independent of the UNFCCC, provides support to the group of least LDCs as they prepare NAPAs. Following their completion, additional funds could be made available to assist these countries to implement the NAPAs. This development-focused fund became operational in July 2001.

⁵ www.rockfound.org. The Rockefeller Foundation is the major supporter of the Asian Cities Climate Resilience Network, a USD 70 million effort designed to improve the resilience of major cities in the Asian continent against the impacts of climate change.

climate impacts over space and time (Liverman 2010). The spatial aspect is particularly important because the effects of climate change will be felt differently across landscapes. Decisions for adaptation funding will have to account for the location of populations, available resources, and scope of impacts in that particular area. Mapping and spatial information related to climate impacts and adaptive responses is a key piece that has thus far been missing from the decision making process for adaptation. Here, we present a tool that can fill that gap.

THE GLOBAL ADAPTATION ATLAS

To enable the translation of scientific information into a form that could have a useful influence on policy decisions and adaptation resource allocation, we created the Global Adaptation Atlas.⁶ With geography as one of the primary links between impact science and adaptation activities, the Atlas was designed to be a web-based, dynamic mapping, and visualization tool that can help prioritize research and action on adaptation. The Atlas strives to achieve this goal through a collation of the peer-reviewed literature that focused on the projected human impacts due to climate change to identify the gaps in the scientific literature, as well as to collate the best available information on past, current, and future adaptation activities so as to help create a “community of practice.”

The activities envisioned that the Atlas can assist with include:

- (a) identification of the major research gaps in the peer-reviewed literature on the impacts and areas less studied;
- (b) tracking of financial commitments, disbursements, and effectiveness of funding provided by the various parties to the UNFCCC and other crucial donors;
- (c) recognition and tracing trends between adaptation and development activities;
- (d) observation of issues that adaptation activities address in their objectives;
- (e) enhancing the ability of local, national, regional, and global decision and policymakers to coordinate, collaborate, and understand ongoing activities, and to plan for expected impacts.

ARCHITECTURE OF THE ADAPTATION ATLAS

The Atlas’s information depository consists of two main parts: data derived from the peer-reviewed literature on the human impacts of climate change, and details on adaptation

activities from various actors. Much of the early literature on the impacts of climate change revolved around the expected temporal and spatial changes in temperature and precipitation. The Atlas focuses on the section of the literature that dives one step deeper: what are the impacts that will manifest as a result of changes in temperature and precipitation on such things as crop yields, disease vectors, and surface water runoff? The Atlas is a human-centric tool and focuses on scientific and model findings that address impacts on human activities. The tool contains data on the impacts of climate change and adaptation activities, spanning five different themes: food, water, land, health, and livelihood.

To collect this information, the Atlas team first conducted a literature review in late 2008 and early 2009. The team identified papers that were relevant and applicable to the goals of the tool and contacted their respective authors to obtain the results of their work. The Atlas, to a large extent, relies on the willingness of published academics and scientists to share their results and information. Out of 200 studies identified, only 22 authors responded with their consent and relevant data. Of these, 16 studies eventually populated the Atlas, as shown below in Table 1.

These data were then spatially represented using ArcGIS software (a mapping program), prior to their inclusion into the tool. Each study was tagged with the appropriate Atlas theme, designated by color,⁷ and was connected to a future climate storyline. The storylines used in the Atlas were taken from the IPCC Special Report on Emissions Scenarios (SRES) as part of the Third Assessment Report in 2000. The four major storylines, as defined in the SRES are:

- A1 storyline and scenario family: a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and rapid introduction of new and more efficient technologies.
- A2 storyline and scenario family: a very heterogeneous world with continuously increasing global population and regionally oriented economic growth that is more fragmented and slower than in other storylines.
- B1 storyline and scenario family: a convergent world with the same global population as in the A1 storyline but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies.
- B2 storyline and scenario family: a world in which the emphasis is on local solutions to economic, social, and environmental sustainability, with continuously increasing population (lower than A2) and intermediate economic development (Nakicenovic et al. 2000).

⁶ Available at www.adaptationatlas.org.

⁷ The relevant color schemes are food—green, water—blue, land—brown, health—red, and livelihood—purple.

Table 1 Study results populating the data layers of the Adaptation Atlas

Data source	Atlas impact sector	Type of results	Timeframe	Geographic extent
Alcamo et al. (2003)	Water	Water availability (model results)	2050	Global
Dilley et al. (2005)	Water	Cyclone, drought, flood frequency	1960–1990	Global
Doll and Florke (2005)	Water	Groundwater recharge (percentage)	2050	Global
Dronin and Kirilenko (2008)	Water	Drought frequency (percentage)	2020	Russian Federation
Dronin and Kirilenko (2008)	Livelihood	Share in food consumption (percentage)	1960–1990	Russian Federation
Evans (2008)	Livelihood	Increase in duration of dry season in months (model results)	2050	Western Asia
FAO (2006a)	Health	Undernourished populations	1960–1990	Global
FAO 2006b	Livelihood	Agricultural labor force (percentage)	1960–1990	Global
Hales et al. (2002)	Health	Probability of dengue fever (model results)	1960–1990	Global
Matzarakis and Amelung (2008)	Health	Physiological equivalent temperature changes (model results)	2080	Global
Milly et al. (2005)	Water	Surface runoff decline (percentage)	2020–2080	Global
Monfreda et al. (2008)	Food	Crop yields per harvest	1990–2010	Global
Parry et al. (2004)	Food	Changes from 1970 to 2000 crop yield averages	2050–2080	Global
Rowley et al. (2007)	Land	Vulnerability to 1 m sea level rise	1990–2010	Global
Tanser et al. (2003)	Health	People exposed to malaria (model results)	2020	Global
Tanser et al. (2003)	Health	Changes in months suitable for malaria transmission	2050–2080	Africa
Vafeidis (2008)	Land	People flooded by sea level rise (model results)	2080–2100	Global
Vafeidis (2008)	Land	Land lost and submerged by sea level rise (model results)	2050–2100	Global
Vafeidis (2008)	Land	Migration due to land lost (model results)	2050–2100	Global
Vafeidis (2008)	Land	Sea level rise since 1995 in m	1990–2100	Global
WHO (2009)	Health	Reported cases of malaria in 2007	1990–2010	Global

Each paper used in the Atlas was treated as a unique story that had a separate representation of possible climate outcomes because a single study could provide anywhere from a single data layer to up 129 different layers, dependent on the combination of theme, years, climatic scenarios, locations and amount of modeling runs. Other unique characteristics used to filter the papers were the time-frame of projected impacts (2020, 2030, 2040, 2050, 2080, and 2100), and the type of projection, whether it was a raw projection or a percentage change from a specified baseline. For example, Parry et al. (2004) provides the Atlas with the most combinations of data at 129—as the study examines the baseline scenarios of crop production, as well as raw yield projections and changes in these yields across seven different IPCC scenarios and five different time frames (Fig. 1).

These unique characteristics were used as a filter system to ensure that data projected to different time frames or under different scenarios could not be viewed concurrently, as they were fundamentally based on differing assumptions. The tool allows for single impact layer views or multiple impact views. Single layer views allow the user to examine

each unique combination of information individually, while the multiple impact view allows users to combine different layers to see where impacts may occur concurrently. This data combination is a simple stacking of each layer where darker colors represent both the expected magnitude of the individual impact and the presence of other impacts (Fig. 2).

Along with climate impact findings, the Atlas also has detailed information on adaptation activities collected from different sources, with descriptions of initiatives and donors, including development and research organizations. Information on adaptation actions are collected from various sources. In the first iteration of the Atlas, the team sourced information from UNDP's Small Grants Programme,⁸ the World Resources Institutes' *Weathering the Storm* (McGray et al. 2007), the UNFCCC's Local Adaptation Actions Database,⁹ and finally, other organizations such as InterAction,¹⁰ and SouthSouthNorth.¹¹

⁸ <http://sgp.undp.org>.

⁹ <http://maindb.unfccc.int/public/adaptation>.

¹⁰ www.interaction.org.

¹¹ www.southsouthnorth.org.

Fig. 1 Predicted land loss from coastal erosion in 2050 with specific adaptation activities as shown in the Adaptation Atlas. Darker colors denote greater coastal erosion and activities are represented by *blue dots*. Findings represented came from Vafeidis (2008)

Fig. 2 Confluence of changes in cereal crop production and surface runoff changes (by percent) from a baseline of 1900–1970 for North America as represented in the Adaptation Atlas. Data layers include results from Milly et al. (2005) and Parry et al. (2004)

To include the widest range of adaptation activities possible, we included any initiative that the provider of information termed as adaptation, and did not place any restrictions on the types of projects included. Activities currently included in the Atlas span from research endeavors to plans and implementation of activities on the ground. This lack of prior definition may allow researchers to track possible changes in what is considered to be adaptation over time. Further, it could also allow analysts to track various efforts on research and planning (for example, activities such as designing a local or national adaptation plan, or performing risk and vulnerability assessments) versus implementing, monitoring, and evaluating on the ground adaptation activities.

Similar to the scientific information collated in the Atlas, the activities listed are categorized by the themes they address. In most cases, adaptation activities are designed to address multiple issues, and so activities were tagged to both a primary and secondary theme. To enable the research, planning, tracking, and monitoring functions of the Atlas, we collected the following details for each project: name, implementing organization(s), sponsoring organizations with financing commitments, location, and a brief description of undertaken activities. Wherever possible, we collected information on the start dates and duration of the project, in addition to contact details, project websites, and other related activities. Activities can be filtered by their type, donor, amount of resources devoted, and year of inception (Fig. 3).

HARNESSING THE ATLAS: USER OUTREACH AND LONG-TERM TRACKING

The Atlas aims to enable a sustainable community of practice around the issues of adaptation. The community of practice, in the broadest sense, encompasses all of the actors that are either tangentially or wholly involved in furthering research, policy, and action on adaptation, such as international climate negotiators, national policymakers, on-the-ground actors, and the general public. To support this capability, the tool is designed to allow users to register for personalized accounts. The account allows users to select their preferences on their themes, locations, and topics of interest. In future iterations, the tool will provide tailored feedback to users on newly uploaded information. For example, if a user was interested in adapting to desertification, the Atlas would recommend other relevant information based on the same keywords associated with other projects or impact layers. Users are also allowed to comment and provide feedback on projects or research of which they are aware.

The wealth of information contained in the Atlas lends itself to multiple uses and audiences. At minimum, the Atlas is a resource for researchers and planners (spanning the different implementing actors and sponsoring organizations) of adaptation activities. Visual information on projected impacts and current adaptation activities may facilitate these communities in identifying gaps in research and responses, possibilities for further development of their

Fig. 3 Adaptation Atlas information window on existing water adaptation project in Samoa. Atlas users can access this window for all adaptation projects in the Atlas

The screenshot shows a web application window titled "Activity Details" with a close button (X) in the top right corner. The main heading is "Upgrading a Coastal Spring for the Village of Vailoa-Palauli". Below this, the following information is displayed:

- Activity Type:** Project
- Status:** Ongoing
- Funding Source:** Intergovernmental Organization
- Location(s):** Vailoa Palauli, Samoa
- Start Date:** August, 2006 **Duration:**
- Total Funding:** \$11,111
- Recipient:** UNDP, Komiti a Tina ma Tamaitai (KTT)
- Description:** The village of Vailoa Palauli depends on its coastal springs as its main water source for community use. The village is blessed with an abundance of freshwater springs, however most water from the natural springs runoff to the sea and had been wasted. The problem with the high water wastage is that this water could be conserved and utilized during the period of flooding which causes dirty water, and during the dry season.
- Other Themes:** Livelihood, Samoa

There is a blue water drop icon to the right of the status and funding source information. A "Project Website" link is visible in the top right. A vertical scrollbar is on the right side of the description text. At the bottom right, there is a button labeled "Save Activity to My Atlas".

respective agendas, and areas where maladaptive actions may be present in the overall agenda.

On a global scale, the tool can allow for financial accountability under the UNFCCC framework. As the mechanisms of the Green Climate Fund and fast-start funding regimes are solidified, the tool can help donors, recipients, and civil society organizations track, in an open and transparent way, the flows of support toward adaptation. Finally, the Atlas also serves as an educational tool for individuals and educators in the general public. Educators and the public are guided through the easy-to-use tool so as to enable their understanding of the current and future projected impacts in their areas of concern. These users are also able to access vital information on the activities that are planned, under implementation, or completed in their respective areas. In addition, users can contribute studies and results that they find useful or wish to share will colleagues by submitting them to the Atlas, where they will be subject to the same filtering standards as the studies currently within the Atlas.

As it stands, the Atlas is in its alpha version, meaning that it is fully functional, but has not yet reached a large proportion of its intended audience. The next phase in its development is to cultivate a community of practitioners and academics who can utilize it and test its applicability. As the testing process moves forward and more users take

advantage of the Atlas's database to add other studies, the information housed in the Atlas will become more extensive, both in terms of impacts and adaptation projects. With this accumulation of results, the Atlas will lend itself more easily to longer term analysis. On-the-ground actors will be able to use it to track specific projects and gauge their effectiveness over the lifetime of their funding lives, which will help funders and implementing officials better understand what types of actions are most useful in specific areas. Long-term analyses can help identify successful projects as well as maladaptations that should be discontinued or discouraged in other areas.

Similarly, long-term result tracking in the Atlas will contribute to future policymakers and academics' understanding of how project funding responds to particular expected impacts. For instance, one might expect to see more water-enhancement related projects in areas where major impacts to surface and groundwater are expected. The Atlas may help illuminate if this expected pattern holds and will also help reveal what types of projects are being supported in certain areas as adaptation efforts move forward. As such patterns reveal themselves, independent funders can utilize the Atlas to help determine if they wish to invest their resources in specific regions. Similarly, policymakers may use the Atlas to monitor fund deployment over time to help ensure those most in need are receiving assistance.

Fig. 4 Effectively adapting to a changing climate represents one of the most formidable challenges facing the international community over the next century. Photo by José A. Warletta (Stock.xchng)

OPPORTUNITIES MOVING FORWARD

The ability of the Adaptation Atlas to inform multiple audiences on adaptation issues will expand with its user base and its data catalog. In the Atlas's initial development stages, information gathering was primarily geared toward study results and datasets with a global extent. The vast majority of data layers currently in the Atlas are global, with some regional focus on Africa and the Middle East.

This was an appropriate approach for two reasons. First, the Atlas is designed to be accessible to users in both developed and developing countries who are interested in tracking projected climate impacts or existing adaptation funding. Phase One of the Atlas construction necessarily took a global perspective to showcase the capabilities of the visualization of data and to show how it can be useful for tracking understanding of impacts and investment flows across different scales. Second, much of the important impact model results and information on existing adaptation projects was available globally. In tackling the challenge of populating the Atlas with salient and accessible studies, the production team chose to set the foundation for future users with large datasets that highlight the heterogeneous impacts that countries and separate regions will experience.

As it is currently built, the Atlas is an implement with great potential to allow policymakers, scientists, and citizens to see the geography of climate change impacts and coordinated human responses. It provides a framework and methodology through which one can more easily access portions of the scientific literature and adaptation activities. As a dynamic mapping tool that can assist critical resource decisions, it will evolve and expand its current scope to address decision makers' needs. Major avenues through which the Atlas can increase its current usability include focusing collection of results on a more regional scale to show smaller scale impacts, expanding the current user community and encouraging it to actively contribute to the Atlas, and confirming the best data are entering the Atlas through continued verification of findings and meta-analysis (Fig. 4).

CONCLUSION

The challenges of adapting to climate change include not only just responding properly to anticipated impacts and increasing the resilience of vulnerable communities but also working to ensure that decision makers have the proper tools to make informed decisions. The Adaptation Atlas is such a tool. Its ability to represent projected climate impacts spatially along with current on-the-ground efforts will allow policy actors who utilize it to move forward with a better

understanding of existing responses. Moreover, it can help illuminate scientific gaps in the expected challenges for adaptive responses. It is a framework with great potential that will hopefully play an active role in assisting the world adapt effectively to climate change.

REFERENCES

- Agrawal, A. 2008. The role of local institutions in adaptation to climate change. Paper prepared for the social dimensions of climate change, social development department. Washington: The World Bank Group. Retrieved from <http://www.icasus.info/wp-content/uploads/2009/11/agrawal-adaptation-institutions-livelihoods.pdf>.
- Alcamo, J., P. Döll, T. Henrichs, F. Kaspar, B. Lehner, T. Rosch, and S. Siebert. 2003. Development and testing of the WaterGAP 2 global model of water use and availability. *Hydrological Sciences* 48: 317–337.
- Barr, R., S. Fankhauser, and K. Hamilton. 2010. Adaptation investments: A resource allocation framework. *Mitigation and Adaptation Strategies for Global Change* 15: 843–858.
- Brown, J., and N. Kaur. 2009. *Financing adaptation: Matching form with function*. ODI Background Note. London: Overseas Development Institute.
- Dilley, M., R.S. Chen, U. Deichmann, A.L. Lerner-Lam, M. Arnold, J. Agwe, P. Buys, O. Kjekstad, B. Lyon, and G. Yetman. 2005. Natural disaster hotspots: A global risk analysis, Version 1. Disaster Risk Management Series, No. 5. Washington: The World Bank.
- Doll, P., and M. Florke. 2005. Global-scale estimation of diffuse groundwater recharge. Frankfurt Hydrology Paper 03. Institute of Physical Geography, Frankfurt University.
- Dronin, Nikolai, and Andrei Kirilenko. 2008. Climate change and food stress in Russia: What if the market transforms as it did during the past century? *Climatic Change* 86: 123–150.
- Evans, J.P. 2008. 21st century climate change in the Middle East. *Climatic Change* 92: 417–432.
- FAO 2006a. FAOSTAT, Food and Agriculture Organization of the United Nations. Online Statistical Service. Rome: FAO. Retrieved from <http://faostat.fao.org>.
- FAO. 2006b. FAOSTAT, Food and Agriculture Organization of the United Nations. Food Security Statistics, 2006. http://www.fao.org/es/ess/faostat/foodsecurity/index_en.htm.
- Govender, S. 2010. What types of information are needed for climate change adaptation decision making in Africa? Expert perspectives series written for the world resources report 2010–2011. Washington: World Resources Report. Retrieved from <http://www.worldresourcesreport.org/responses/what-types-information-are-needed-climate-change-adaptation-decision-making-africa>.
- Hales, S., N. de Wit, J. Maindonald, and A. Woodward. 2002. Potential effect of population and climate changes on global distribution of dengue fever: an empirical model. *Lancet* 360: 830–834.
- Liverman, D. 2010. Informing Adaptation. *Expert Perspectives Series Written for the World Resources Report 2010–2011*. Washington: World Resources Report. Retrieved from <http://www.worldresourcesreport.org/nl/responses/informing-adaptation>.
- Macauley, M. 2010. Climate adaptation policy: The role and value of information. RFF Issue Brief 10-10. Washington: Resources for the Future. Retrieved from <http://www.rff.org/Publications/Pages/PublicationDetails.aspx?PublicationID=21157>.
- Matzarakis, A., and B. Amelung. 2008. Physiological equivalent temperature as indicator for impacts of climate change on

- thermal comfort of humans. In *Seasonal forecasts, climatic change, and human health*, ed. M.C. Thomson, R. Garcia-Herrera, and M. Beniston, 234. New York: Springer.
- McGray, H., A. Hammil, R. Bradley, E.L. Schipper, and J.E. Parry. 2007. *Weathering the storm: Options for framing adaptation and development*. Washington, DC: World Resources Institute. Retrieved from http://pdf.wri.org/weathering_the_storm.pdf.
- Milly, P.C.D., K.A. Dunne, and A.V. Vecchia. 2005. Global pattern of trends in streamflow and water availability in a changing climate. *Nature* 438: 347–350.
- Monfreda, C., N. Ramankutty, and J. A. Foley. 2008. Farming the planet: 2. Geographic distribution of crop areas, yields, physiological types, and net primary production in the year 2000. *Global Biogeochemical Cycles* 22: GB1022. doi:[10.1029/2007GB002947](https://doi.org/10.1029/2007GB002947).
- Muller, B. 2008. International adaptation finance: The need for an innovative and strategic approach. EV 42. Oxford: Oxford Institute for Energy Studies. June 2008.
- Nakicenovic, N., J. Alcamo, G. Davis, B. de Vries, J. Fenhann, S. Gaffin, K. Gregory, A. Grübler et al. 2000. *Special report on emissions scenarios: A special report of Working Group III of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press. Retrieved from <http://www.grida.no/climate/ipcc/emission/index.htm>.
- Parry, M.L., C. Rosenzweig, A. Iglesias, M. Livermore, and G. Fischer. 2004. Effects of climate change on global food production under SRES emissions and socio-economic scenarios. *Global Environmental Change* 14: 53–67. doi:[10.1016/j.gloenvcha.2003.10.008](https://doi.org/10.1016/j.gloenvcha.2003.10.008).
- Rowley, R.J., J.C. Kostelnick, D. Braaten, X. Li, and J. Meisel. 2007. Risk of rising sea level to population and land area. *EOS Transactions AGU* 88(9): 105–116.
- Tanser, Frank C., Brian Sharp, and David le Sueur. 2003. Potential effect of climate change on malaria transmission in Africa. *The Lancet* 362: 1792–1798.
- Vafeidis, A.T. 2008. A new global coastal database for impact and vulnerability analysis to sea-level rise. *Journal of Coastal Research* 24: 4.
- World Health Organization (WHO). 2009. Global Health Atlas. Geneva: WHO. <http://www.who.int/globalatlas>. Retrieved 24 June 2011.

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