



Adapting Agriculture to Climate Today, for Tomorrow (ACToday)– Climate and Food Security

Executive Summary

Food security is a key part of the United Nations' second Sustainable Development Goal (SDG 2), which aims to end hunger around the world. Public and private programs designed to address a lack of food security exist across the developing world. But the role of climate, and climate information, is often overlooked in efforts to increase food production and security and achieve SDG 2.

This Columbia SIPA field research case looks at an innovative Columbia World Projects effort, called Adapting Agriculture to Climate Today, for Tomorrow. ACToday, as it is known by, aims to help countries improve their climate information systems and better adapt agriculture to climate change and variability. The case outlines ongoing field research in Senegal, Ethiopia, Bangladesh, Colombia, Guatemala, and Vietnam – with a particular focus on the work done by SIPA student researchers in that country – and includes interviews with Columbia field researchers and project leaders including Lisa Goddard, Director of Columbia's International Research Institute on Climate and Society; John Furlow, ACToday Vietnam project lead; and Avril Haines, Senior Research Scholar and Deputy Director of Columbia World Projects.

The case includes the following elements;

- a) Video Intro and Discussions – Available Online
- b) Written Case Study (This Document)
- c) Appendix A – Original Documents

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Climate Change and Hunger

The reality of climate change and climate variability has become a generally-accepted scientific fact. Rising temperatures and dramatic weather events have led to global efforts to prevent further increases in carbon emissions. But efforts are also under way to adapt to a “new normal” in which seasonal weather patterns no longer follow traditional norms.

Most scientists agree that one of the areas in which climate change will have a particularly drastic impact is agriculture. The world’s global food systems have developed over thousands of years, and have adapted to anticipated local temperatures and rainfall totals. With more than 80 % of the world’s agriculture dependent on rain, small changes in total amounts, or changes in the timings of annual rains, can have potentially dramatic negative impacts on food production.

One of the leading actors in efforts to understand the impacts of climate change on the global economy is Columbia’s Earth Institute, a research center established in 1995, and which was led by economist Jeffrey Sachs from 2002-2016. Sachs is the author of bestselling books such as *The End of Poverty* and *The Age of Sustainable Development*. He was a key player in developing and promoting the Sustainable Development Goals and in theorizing the long-term impacts that a changing global climate would have on the world’s food production. In 1996, Columbia University and the U.S National Oceanic and Atmospheric Administration established the International Research Institute for Climate and Society, or IRI, at the University’s Lamont campus, located in Palisades, NY, about 15 miles north of Morningside campus. The new institute was dedicated to mapping and researching the impact of climate on development.

The focus of IRI, from its inception, was to study and evaluate both the short and long-term impacts of climate change. For IRI Director Lisa Goddard, one of the key areas where more research is needed is on the medium-term impacts of climate change, rather than longer-term models. “*Having the capacity to produce forecasts for the next couple of weeks to the next couple of years, all those things are desired by these ministries and by the farmers – but it just doesn’t exist,*” Goddard said. IRI aims to leverage scientists’ expertise to meet the needs of people on the ground.

Climate Variability

In studying climate data from around the world, IRI researchers began to realize that one of the key ways that long-term climate change manifested itself was by increased year-to-year variability in weather. “These countries do face very serious impacts when the rainy season doesn’t play outright, as either it doesn’t rain or when it does, it is delivered in very intense flooding events,” Goddard explains.

IRI researchers realized that while global temperatures were increasing at a slow but steady pace, the increased variability was bringing with it huge costs in lost agricultural production. Farmers must make complex decisions each year on when to plow, when to plant, and when to apply fertilizers, based on estimated and expected seasonal weather conditions. When weather does not conform to historical norms, making such decisions becomes much harder.

“Farmers are on the front line of these year to year climate fluctuations and as they are dependent on rain-fed agriculture, if they have a drought year or get too much rain – That is a real problem for them”¹

Agricultural systems in highly-developed countries have been able to shield themselves from some of the impacts of this climate variability through advanced weather forecasting, as well as government-sponsored crop insurance and subsidies. Much of the developing world does not have access to such insurance, and weather forecasting systems in many countries are underdeveloped, and not linked to agriculture decision-making. In many countries, meteorological systems were originally developed for military and aviation needs, and only aim to serve those ends:

“In developing countries and especially in Communist countries, the meteorological service exists to serve the military in aviation needs”²

El Niño Opportunity - Forecasting in the Tropics

Although tropical countries in the developing world are some of the most vulnerable to climate change, their location provides an unusual opportunity. Two of the most well-known and studied long-term weather patterns are the El Niño and La Niña currents, which occur on a six-year cycle. Warm currents from the central Pacific Ocean oscillate in temperature as El Niño becomes La Niña, which introduces predictable swings in annual temperature and rainfall in tropical countries from South America to Africa and Southeast Asia.

Lisa Goddard, one of the world’s leading experts on the El Niño phenomenon, believes that by incorporating El Niño data with historic climate data and new predictions based on climate change, more accurate seasonal forecasting is possible, especially for countries in the tropics.

IRI – Managing Climate Services

IRI’s core mandate is to both study weather patterns and create predictive models, but also to enable this information to impact policy. For this reason, since its inception, its team has

¹ Quote from Lisa Goddard in interview with Adam Stepan

² Quote from Lisa Goddard in interview with Adam Stepan

been made up of people from a wide variety of disciplines, including climate scientists, social scientists and atmospheric engineers. It has also put a strong emphasis on translating climate information and models into publicly-accessible digital map rooms, climate projections and temporal weather-based data which can be used by governments and organizations to better adapt their development plans and policies to varied climate scenarios.

Some of the center's earliest projects included a climate information services project—Enhancing National Climate Services initiative, or ENACTS. For that project, which is based out of Rwanda, IRI worked with the national meteorological services to deliver robust climate data, targeted information products and training specific to local needs, in order to help the country attain its sustainability vision for 2020.

Seasonal Predictions in Uruguay

In 2014, IRI began a major new initiative, designed to build on the methods and techniques developed in the ENACTS project in Africa by working with authorities in a new country to implement them on a new scale. IRI researchers chose Uruguay, home country of Senior IRI Research Scientist Walter Baethgen, as the site for the new initiative. Uruguay is a small country in South America with a population of nearly 3.4 million, located between Brazil and Argentina. Agriculture makes up 18.2 %³ of its gross domestic product (GDP) and 87%⁴ of its land use.

Increased climate variability and the impacts of climate change have had a profound impact on Uruguay's agricultural output. Baethgen organized a consortium of Columbia scientists and local Uruguayans to address the issue.

With a \$10 million loan from the World Bank, IRI, the Uruguayan National Agricultural Research Institute and the Ministry of Livestock, Agriculture and Fisheries designed a program aimed at bringing a detailed decision support tool to the Uruguayan agriculture sector. The system would be fed with dynamic seasonal climate forecasts, information about soil moisture levels, crop varieties, fertilizer needs and rainfall patterns. This information would then be adapted to make it accessible and understandable to agriculture extension workers and farmers.

Working with their local partners, IRI created an [online dashboard](#) to allow Uruguayan farmers to look up and find seasonal weather predictions for their region made on a one-to-three-month time frame. The system allowed key decisions to be made on when to plant, what fertilizers to use, and whether to invest in new irrigation systems.

³ <https://tradingeconomics.com/uruguay/gdp>

⁴ https://www.indexmundi.com/uruguay/land_use.html

“The idea of this project is to provide farmers with cutting-edge climate data in terms that anybody can understand”⁵

The system implemented in Uruguay was a state-of-the-art way to bring climate information into the decision making framework of both government institutions and local farmers, and delivered impressive food production gains in the country. One of the questions that researchers posed coming out of the project was whether the Uruguay initiative could serve as a model for a wider global program. Could the tools and methods developed in Uruguay be applied and replicated in other countries facing similar problems?

Enter Columbia World Projects

A series of events at Columbia would allow IRI researchers a chance to test their model sooner than they had anticipated. For a number of years, Columbia University President Lee Bollinger had been involved in a radical rethinking of the role of Columbia as a research university. A key component of Bollinger’s vision was the conviction that Columbia should engage with global problems and forge on-the-ground connections with local actors around the world. The Columbia Global Centers, a series of new research outposts the first of which opened in 2009, were a key part of this initiative. Since 2009, Columbia has opened Global Centers in Amman, Beijing, Istanbul, Mumbai, Nairobi, Paris, Rio, Santiago and Tunis.

These global centers were created not as remote campuses, but as centers for research and local engagement. They aim to connect Columbia researchers with local leaders, and focus and connect scholarship across regions.

In the spring of 2017, President Bollinger’s second major global initiative was announced – Columbia World Projects.

Headquartered at the newly-inaugurated Forum building on Columbia’s Manhattanville campus, Columbia World Projects (CWP) aims to use university research to tackle global challenges and positively affect people’s lives. Its goal is to connect scholarship with pressing social issues, and to design and execute projects that could be implemented and show results within a three to five-year timeframe.

Nicholas Lemann, Dean Emeritus and Pulitzer-Moore Professor of Journalism at Columbia, and a staff writer for *The New Yorker*, was chosen to lead the new initiative. Avril Haines, a former Deputy National Security Advisor to President Obama and Ira Katznelson, Ruggles Professor of Political Science and History at Columbia, joined the organization as deputy directors.

⁵ Baethgen, Walter: *seeds of hope*, IRI; <https://iri.columbia.edu/news/seeds-of-hope/>

“At CWP, we are trying to develop a platform where research and scholarship can come to bear on a big fundamental social challenge”⁶

Senior staff in the office of Columbia University President Lee Bollinger decided that Columbia World Projects’ first project would build on the success of IRI’s work in Uruguay, expanding that work to several countries around the world. The project would be called Adapting Agriculture to Climate Today, for Tomorrow, or ACToday.

ACToday

Over the course of 2016-2017 the broad strokes of what would become the ACToday project were drawn up. IRI Director Lisa Goddard worked with Columbia World Projects leadership and other key partners to design a program that would serve as a model for other Columbia World Projects, and CWP funding was provided to finance the five-year, multi-country endeavor. Like the Columbia World Projects that will follow it, the first project would focus Columbia research on a large and important issue – global food security and would also bring together a range of local and international partners.

The project would focus on how to protect food security in the face of increased climate variability in six countries: Bangladesh, Colombia, Ethiopia, Guatemala, Senegal and Vietnam, six countries that are among the most vulnerable in the world to climate change. The goal was to apply the model developed successfully in Uruguay in these countries, working with local governments to develop and implement sophisticated local climate modeling and information systems, and then implementing systems to get this climate data to local farmers. If the countries could be helped as Uruguay had been, and if detailed climate models and predictions could be made available, it could have important effects on food production and food security, and have additional positive effects in areas such as public health and security.

The six ACToday countries all also already had government buy-in to the importance of adapting to climate change, and local operations from IRI’s key local partners such as The International Center for Tropical Agriculture (CIAT) and the World Food Programme (WFP). Agriculture was central to each country’s culture and economy, and their geographic diversity meant that the replicability of the Uruguay’s project ideas could be tested in a range of new settings: “These countries gave a diversity across geographies and cultures and even the politics to test out some of the ideas and implementation of those ideas.”

⁶ Quote from Avril Haines in interview with Adam Stepan

Engaging Field Researchers: SIPA's MPA-DP Program

One key project need was to find and engage a team of field researchers to conduct country evaluations. The Master of Public Administration – Development Practice, or MPA-DP program at Columbia's School of International and Public Affairs (SIPA) was chosen as a partner for this effort. Run since 2009 by Professor Glenn Denning, an expert in food systems who has overseen complex multi-year research projects in Vietnam and Timor-Leste, the graduate program trains students in technical, social and political elements of policy creation and program monitoring. Every summer, it sends some 60 graduate students for summer placement field research, often working in conjunction with host country governments and international development organizations such as the WFP, the Asian Development Bank and the World Bank.

"We are able to match students with certain interests with the priorities we needed to be addressed in those countries."⁷

Following a selection process in the fall of 2017, 13 MPA-DP students were selected for the first round of ACToday project fieldwork, and broken into six two-person country teams (one student was assigned to the WFP headquarters in Rome). The mission for their initial three-month summer placement was to map each country's existing food production value chain, and their current systems for the creation and dissemination of information about climate. They would also engage with local government officials with the goal of understanding who the local players and actors were and who would need to be engaged in each country to implement a national climate information program.

Work began in the spring of 2018, with research efforts getting underway at SIPA and Columbia's Lamont-Doherty campus. IRI project leaders visited local countries and met with local partners, so that permissions and logistics for extensive summer fieldwork would be in place.

Close-Up: Vietnam

Each of the ACToday countries posed unique opportunities and challenges. As a lens into some of the broader issues and discoveries, this case study focuses on the work of student researchers in Vietnam.

With more than 2140 miles of coastline, Vietnam is a country that has been and will continue to be significantly affected by changing climate; it was ranked in the top 10 countries most vulnerable to climate change by the United Nations Framework Convention on Climate Change. With a large percentage of its agriculture located near the coast, changes in ocean temperature have a direct impact on levels of annual rainfall and the

⁷ Glenn Denning quote from interview with Adam Stepan

timing of monsoons. Vietnam has also seen a dramatic increase in drastic weather events, with annual typhoons increasing and resulting in major economic losses, as stated by the World Bank, which determined that nearly 1.5% of the country's GDP was lost between 1989 and 2008⁸.

The country offered a unique set of challenges for ACToday: Unlike other countries where IRI partners such as CIAT and the World Health Organization (WHO) had a long history of action, CIAT's offices in Hanoi were made fully operational only in 2015, and IRI had little direct contact with Vietnamese officials before 2017. It was also the only "command economy" in the group of six, and decisions on agriculture and other areas of economic activity were tightly centralized and controlled by the country's Communist party. John Furlow, deputy director for humanitarian and international development and country lead for Vietnam at IRI states that "*we have to work within the system that is there to understand how best to overcome those challenges.*"⁹ Critical to IRI's impact in Vietnam was their understanding of the local culture and bureaucratic structure.

The country also had certain advantages as a partner for the ACToday project. IRI had been active in regional climate conferences, and its work creating climate models and maps was known and admired by Vietnamese officials. The fact that the Vietnamese Communist party offered a powerful central command and control also meant that if new climate services were put in place, there were structures in place to ensure that this new information would reach village farmers.

The research goal for the first phase of the project in Vietnam was to map Vietnamese food systems and the educational and communication systems put in place by the Vietnamese government. Two MPA-DP researchers were chosen: Nausher Khan, a graduate student originally from Pakistan focusing on food and nutritional security; and Claire Thibault, a graduate student from France who was previously employed in public education. They were supported by local researchers working out of the Hanoi offices of CIAT and worked closely with Dannie Dinh, an IRI project manager who had moved to the United States from her native Vietnam when she was 13. Dinh had travelled to Vietnam to take part in the initial meetings with Vietnamese officials and would provide key project support during the fieldwork phase.

Agriculture 40 Years After "The American War"

Khan and Thibault arrived in Hanoi, the former capital of North Vietnam, and now the capital of the unified Socialist Republic of Vietnam, in June 2018. Heavily bombed by the United States during the conflict that the Vietnamese now call "The American War,"

⁸ Zhou, Botzen: "*The impact of natural disasters on firm growth in Vietnam*" Utrecht university school of economics, 2017

⁹ Quote from John Furlow interview with Adam Stepan

Hanoi is a city of surprising contrasts. While rice paddies cover the land outside the capital, the city itself is a booming modern metropolis.

While Vietnam remains a Communist state, in which the Party maintains a firm grip on political power, it has experienced a radical economic opening in recent years. Following years of low growth and food insecurity, the government decided to open the Vietnamese economy to private capital from 1986 onwards.

Since 2000, Vietnam has been one of the fastest growing countries in the world, with an annual GDP growth rate of 6.4% – growth powered in large part by major export industries such as textile and electronic equipment.¹⁰ Despite this industrial economic growth, agriculture continues to be vital to the culture and the economy. Rice in particular plays a central role in Vietnamese national identity and in its export earnings.

“Since the 1975 reunification of Vietnam, the government has placed a very high priority on food security”¹¹

Following a series of economic reforms implemented in the 1980s, small-scale Vietnamese farmers have had more control over local production, and Vietnamese rice productivity has grown from two tons per hectare in 1975 to six tons per hectare today. Total production has reached 45 million metric tons in 2017, with nearly 6.7 million metric tons of this earmarked for export¹². Vietnam is now the world’s third largest producer of rice and exports from the country represent a crucial portion of global rice production. According to Denning, who has worked extensively in Vietnam, “we’ve seen Vietnam go through quite an extraordinary transformation since the end of the war in April 1975.”

Yet Vietnam’s great gains in food production since the end of the conflict have been threatened by recent climate events. Increased typhoons and flooding, inconsistent rain patterns and rising sea levels have had a severe impact on Vietnamese agriculture. When sea levels rise, salt water penetrates through coastal tributaries and moves upstream to the paddies of Vietnam’s famous Mekong Delta, where it deposits large quantities of salt. The salt proves disastrous for rice as the crop is extremely sensitive to pH levels of the soil, and with each year, less and less arable land is available for cultivation.

The mountains in the Northern and Central Highlands are also affected by climate and subject to erratic landslides caused by excess rain. These landslides drastically affect coffee production and displace the communities that have resided there for decades. With more than 47% of the country’s labor force employed in agriculture and aquaculture and

¹⁰ World Bank, 2018, <https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG>

¹¹ Quote from Glenn Denning in interview with Adam Stepan

¹² Information from Glenn Denning interview

more than 21% of the GDP derived from these sectors, any changes in weather cause massive ripple effects in the social and economic structure of the nation¹³.

Mapping the Agencies

Khan and Thibault began their work with a series of meetings with government agencies in Hanoi. If changes to policy were to be implemented, it would be essential to understand the hierarchy of local agencies responsible for managing climate information and getting this information to local farmers.

As in many nations, the Vietnamese national weather service was initially set up to provide information for aviation and military needs. As Khan and Thibault proceeded with their initial meetings and mappings, it became clear that Vietnam's current configuration of government agencies allowed for little information on climate to flow to local farmers.

Khan and Thibault did discover some elements in Vietnam's political landscape that could lay the groundwork for developing a new and integrated climate system. One was the fact that the Vietnamese government was officially strongly in favor of international climate accords, and had incorporated the key SDGs of eliminating hunger and taking action on climate change into its national planning. (Vietnam was one of the first signatories of the Kyoto protocol and the Paris climate accords, though the country has not always adhered to the terms of those agreements since signing).

While this official endorsement of climate mitigation as a national priority had not, in early 2018, translated into important policy decisions, it meant that government officials and institutions – and international NGOs working in Vietnam – were amenable to these ideas and focused on finding solutions.

Another important factor was the Vietnamese Communist party itself, and the farmers union that it sponsored. The Vietnamese farmers union is one of modern Vietnam's largest and oldest institutions, with more than 10 million members and a presence in every province and commune in the country. During periods of armed conflict with French and American forces in the second half of the 20th century, the Vietnamese Communist party relied on farmers for food production and political support. Vietnamese farmers had been crucial to the Communist revolt against French and American colonial powers. In 2018, the union remained a major cultural and political force in the country, with a national network of extension agents and local offices in almost every Vietnamese village. While the union currently did not focus its attention on climate issues, ACToday researchers quickly identified it as a potentially important partner for disseminating climate information to farmers across the country.

¹³ CGAIR, 2019; <https://ccafs.cgiar.org/vietnam#.XFvRL89KhHQ>

Field Research

It was agreed that Khan and Thibault would engage in a series of field visits to better understand how climate variability was affecting Vietnamese farmers and what climate information village farmers were currently receiving.

With the help of a translator, they set out on a series of fact-finding trips to the rice-growing area of the central coast, Ha Tinh. The region was selected due to its particular susceptibility to extreme weather events, and the existing presence of a climate smart village called My Loi. The My Loi project was being run by another partner institution called the International Center for Agro-Forestry (ICRAF) and would serve as a comparative benchmark as it demonstrated the impact climate smart agriculture could have on production and farmer knowledge. In Ha Tinh, the team conducted extensive interviews with farmers and agricultural extension workers to determine their needs and to assess the usability of current climate information that these groups could access. After conducting more than 40 interviews, the immediate conclusion was that even though some climate information from the government was reaching the farmers, it was inconsistent, often inaccurate and presented in ways that the farmers could not understand and thus not use.

The team learned that while government information on climate was often incomplete and inaccurate, there was a real need for good data. Khan and Thibault's interviews revealed that most local farmers relied on a series of traditional signs to predict seasonal weather patterns and time their annual planting and harvesting. With growing climate change and climate variability, these signs were no longer reliable, leading to a series of crop failures.

Dannie Dinh, a project manager at IRI, explains that the farmers navigate by checking for certain signs about the weather. "They'll say that if the dragonfly is flying close to the ground, it means that it's going to rain," she said. But these indicators no longer signal what they once did.

How could a new system be put in place, and what would be required so that farmers would rely on it?

A New Model?

Following their research trip to the south, Khan and Thibault held a series of follow-up meetings with officials in Hanoi. The need for better climate information was clear, but how this could be implemented remained to be seen.

It was agreed that the team would visit Moc Chau, a high-altitude region in the country's northwest famous for its production of fruits and vegetables. Moc Chau faces a different set of climate issues than My Loi, and is particularly susceptible to heavy rain and resultant soil erosion.

Upon meeting local district officials, the team also learned that Moc Chau had been selected as part of a new initiative by the Vietnamese government to integrate a variety of different public agriculture-related agencies into one unit. This consolidated unit would include the departments of crop production, agricultural extension services, veterinary services, quality management and general administration. When the research team arrived in July 2018, the new system was still in an implementation stage, uncertainty remained about the new chain of command between agencies. Nonetheless, the reorganization had provided an opportunity to restructure traditional training for farmers, and, if correctly integrated into the extensive farmers union systems, had the potential to radically transform climate services in Vietnam.

The team also evaluated the system of trainings and crop calendars currently in use. These were widely distributed, and provided detailed information and suggestions for plantings, seed types, and the use and timings of inputs such as fertilizer. As of 2018, they did not yet include climate information, nor updates that were dynamic and which responded to seasonal climate predictions. If this network of trainings and calendars could be updated and integrated with climate information, it would seem that rapid progress could be made.

Field surveys and interviews from the Moc Chau region confirmed data from southern region with regard to farmers use of existing Vietnamese over-the-air weather information and predictions provided in television broadcasts and other official channels. As much of this was inaccurate due to insufficient infrastructure, and models that did not key new variables in the earth's changing climate conditions, forecasts were not widely trusted or used by local farmers.

Following their field study, the team returned to Hanoi, and confirmed their initial recommendations with their partners. In their assessment, Vietnam had a great need and appetite for updated climate modeling and seasonal forecasts, and a network in place, in the form of the farmers union that could disseminate such new information. The government had also begun a series of administrative adjustments in the Moc Chau region pilot that allowed public agencies to work together in a more streamlined way and include climate information in their planning. But major investments in sensors and modeling would be needed, as would continuing work with local officials.

Taking Stock and Next Steps

In the fall of 2018, data from ACToday research teams in each of the project's six countries was compiled and compared at IRI, and country research teams were debriefed on the findings.

As data from these very different countries was collected and analyzed, a series of common issues and themes emerged. One was the lack of good historic "benchmark" climate data. For the ACToday plan to work, new and more accurate seasonal climate models would need to be built for each country. These would include global climate data

that IRI already had access to, but would also require more accurate local information on rainfall totals and timings.

Another common thread was the need for all countries to invest in both the technological and human infrastructure needed to develop integrated climate information systems. Data, and accurate climate data, has, as the Uruguay example has shown, the potential to provide dramatic increases in agricultural productivity. But to realize these gains, all six countries would need to make significant investments in their climate measuring and modeling capacity, and in field outreach and training.

A third and crucial takeaway was the continued need to partner with local authorities. While IRI could provide technical knowledge and access to international data sets, project success and continued sustainability would require local leadership and changes to local structures and operations.

Throughout the 2018-2019 academic year, the ACToday team mapped and planned the next stage of work in all six countries. New teams of SIPA researchers will be recruited in the spring and will return to the field with a mandate to build on the initial research, and set the stage for the next stages of the project development.

Unfortunately, the continued climate variability and unexpected climate events will continue to push climate to the forefront of all debates about global hunger.

“The idea is that given that we actually do have climate change by being able to better prepare and anticipate and understand the climate, and have policies in place to support structures that use that information. This can build incremental adaptation to longer term climate change”¹⁴

¹⁴ Quote from Lisa Goddard in interview with Adam Stepan

Appendix A – Original Documents



Figure 1 – Columbia Global Centers Map



Figure 2 – Forum (HQ of the Columbia world projects)



Figure 3 – Vietnamese rice farmer in northwestern region of Moc Chau

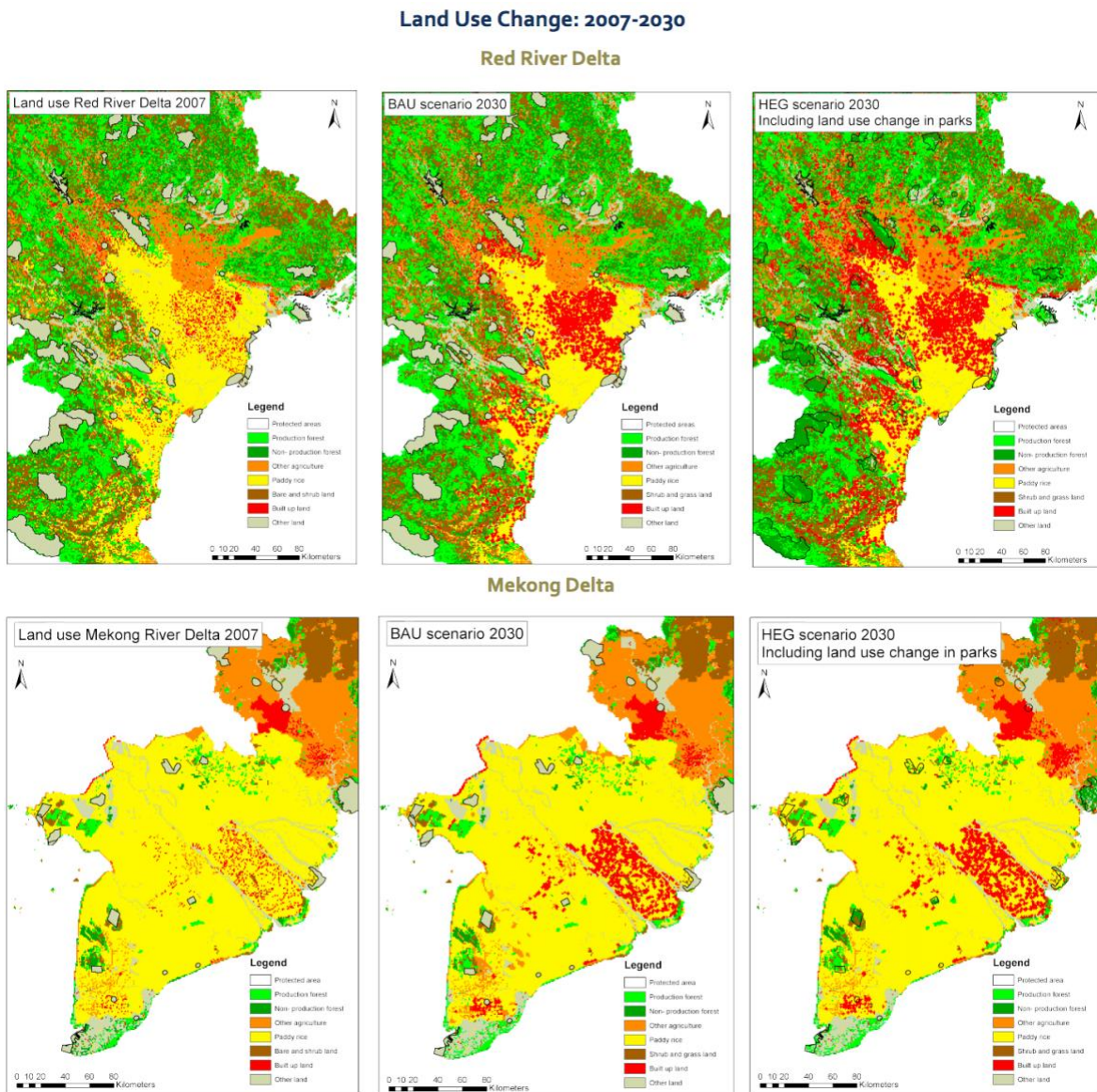


Figure 4 – Land use change projections (Source FIPI Map 2007)¹⁵

Further Global climate projection maps needed from IRI map room

¹⁵ <https://cdkn.org/wp-content/uploads/2012/01/Land-Use-Food-Security-Climate-in-Vietnam-Policy-Brief.pdf>