



The Living Fields: Post Conflict Rice in Cambodia

Executive Summary

Rice has been a staple of the Cambodian economy, diet, and way of life since time immemorial. The story of Cambodia's rice cultivation involves a once-great empire, a devastating war, a radical revolutionary dictatorship that nearly wiped out Cambodian rice from the face of the earth, and one of the world's most interesting stories of post-conflict international cooperation in the service of the preservation of genetic diversity.

This Columbia University audiovisual case study explores the history of rice cultivation in Cambodia before, during, and after the Khmer Rouge "Killing Fields" of the late 1970s. It details agricultural preservation efforts undertaken by organizations such as the International Rice Research Institution (IRRI) and the Cambodian Agricultural Research and Development Institute (CARDI) to answer the practical question of how biodiversity can be preserved even in regions devastated by conflict, as well as the implications it holds for other international development groups working in similar situations. This case includes interviews with individuals affected by the reign of the Khmer Rouge such as Lee Thhert, farmers aided by the efforts of IRRI and CARDI such as Munn Moeun, Yung Yai, and Yeam Savoth, and leading scientists and leaders in the field such as Dr. Ouk Makara, Dr. Buyong Hadi, Dr. Ponh Oudam, and Glenn Denning.

The case includes the following elements;

- a) Video Interviews
- b) Written Case Study (This Document)
- c) Annexes

A Vibrant Past

The land that comprises what is now Cambodia— a small southeast Asian country neighboring Laos, Thailand, and Vietnam—is home to a unique water system and geographic landscape that creates fertile breeding grounds for hundreds of varieties of rice. It sits at the base of the Mekong Delta, which the Tonle Sap River connects to the Tonle Sap Basin. Here, the flow of water reverses annually, swelling and depleting the basin -- creating ideal conditions for the lowland rainfed rice varieties which have become a staple of the region's agriculture.

But before this land was Cambodia, it was home to the impressive Angkor Civilization. Angkor, a sprawling kingdom spanning from the 9th to the 14th century, was home to the most populous and prosperous civilization of its time. Its capital, Angkor Wat-- home to the famous Angkor Wat

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temple—boasted an impressive population of just under 1 million people.¹ To feed this massive populace, Angkor pioneered unprecedented food production through massive labor campaigns and elaborate irrigation systems. These irrigation systems were feats of technological genius at the time, including channels a dozen miles long and nearly 200 feet wide, thousands of acres of reservoirs, and even walled paddies to control flooding.² Six centuries after the Angkor Civilization collapsed, it was this former greatness that the Khmer Rouge strove to restore after taking power.

Colonialism, Conflict, and Communism: Cambodia's Tumultuous 20th Century

The 20th century was full of upheavals for Cambodia, encompassing periods of both extreme hardship and unprecedented growth and innovation. French colonial rule was a prosperous time for Cambodia's agricultural sector, seeing an increase in rice production from 560,000 tons to 1.58 million tons from 1900 to 1950 -- a near three-fold increase over five decades.³ The growth continued into the 1960s and reached its peak production of 3.8 million tons of rice in early 1970. Even so, yields remained limited because a majority of rice production stemmed from extensification, or the cultivation of new land dedicated to agriculture, rather than from innovation. Colonial extractive practices also meant that the majority of the surplus from production was captured by the colonial elite and their local allies, rather than benefiting common Cambodians.

The country's rice production declined during the 1970s, beginning with the devastating impact of the Indochina War, known as the Vietnam War in the United States. Direct bombing raids from the US's Operation Menu resulted in 3,630 flights dropping a total of 110,000 tons of bombs over 14 months in 1970, causing widespread disruption and displacement amongst rural farmers in the countryside.⁴ Bombings continued well into the Vietnam War, and by 1973, an estimated total of 2.7 million tons of bombs were dropped over the region. The sheer volume of the attacks makes Cambodia the most bombed country in history.⁵ Farmers continually fled their fields and flooded the capital of Phnom Penh, swelling the population to nearly 2 million people. Production plummeted, and output decreased by 84% from 1970 to 1975. The country's darkest days had yet to arrive; the end of the Vietnam war ushered in a brutal regime in 1975 as the Khmer Rouge rose to power on April 17. As Dr. Lien-Hang T. Nguyen, professor of history of United States and East Asian relations at Columbia University summed it up:

The goal of what the United States was trying to do in Operation Menu was to destroy all the Vietnamese communist sanctuaries that were located in Cambodia... but what it basically did was caused massive disruption and devastation to the Cambodian countryside.⁶

Reign of Terror: The Khmer Rouge

The Khmer Rouge was a militaristic and totalitarian communist regime that came to power in 1975, supported by the North Vietnamese, Viet Cong, and the Chinese Communist Party.⁷ At its head was Pol Pot, the son of wealthy farmers who was educated in France during the colonial period. Upon his return to Cambodia in 1953, he became a teacher as well as a leader of Marxist nationalist paramilitary groups.⁸

¹ <https://www.sapiens.org/archaeology/how-kings-created-angkor-wat-then-lost-it/>

² <https://www.sapiens.org/archaeology/how-kings-created-angkor-wat-then-lost-it/>

³ Cramb, Rob: *White Gold: The Commercialization of Rice Farming in the Lower Mekong Basin*, 2020

⁴ <https://www.history.com/this-day-in-history/u-s-bombs-cambodia-for-the-first-time>

⁵ https://gsp.yale.edu/sites/default/files/walrus_cambodiabombing_oct06.pdf

⁶ Quote from Dr. Lien-Hang T. Nguyen in an interview with Bernhard Fasenfest

⁷ <https://www.britannica.com/topic/Khmer-Rouge>

⁸ <https://www.britannica.com/biography/Pol-Pot>

The Khmer Rouge recognized the devastation caused by the Vietnam War and the discontent it brewed in rural farmers ripped from their livelihoods. Pol Pot organized a revolution that resulted in a destabilizing civil war. The revolution saw massive support initially, as citizens banded against years of colonial oppression as well as the destructive bombing campaign carried out by the United States. This popular support allowed the Khmer Rouge to take over Cambodia's capital, Phnom Penh, and topple General Lon Nol's US-backed army in 1975. With that, the Khmer Rouge won the civil war and began to dictate the path forward for Cambodia.

Year Zero: A Return to Greatness?

The Khmer Rouge's vision was to return to the former glory of the Angkor Empire by using the same techniques that brought prosperity in the 9th century, namely labor and irrigation. They sought to turn back the clocks, signaling the rebirth of their nation by branding the outset of Khmer Rouge rule "Year Zero." This meant fully severing the country's ties to any western influence and technology in favor of returning to tradition. If Angkor did not need western technology, neither did the Khmer Rouge. As such, the Khmer Rouge's plan rested on two central pillars: massive amounts of brute labor and irrigation reminiscent of Angkor. With this myopic focus, the regime also deemphasized the importance of farmers' knowledge of the complexities of Cambodian rice in favor of a top-down approach that ignored regional variations in growing conditions and differences in rice varieties that have become well adapted to niche environments.

Guided by the slogan, "If we have rice, we have everything," the Khmer Rouge planned to use rice to feed and finance their revolution by reaching a new output of 3 tons/hectare. This, they believed, would not only be enough to process and feed the entire army but would also lead to a surplus that could then be sold for weapons and munitions. But the production of such a high yield required a large labor force and the regime responded by relocating entire cities. Phnom Penh's swollen population of 2 million people plummeted overnight as the regime forcefully shifted millions of urban dwellers to rice paddy fields to work as farmers. The popular support that had been the source of Pol Pot's success in the civil war quickly soured as life for the Cambodian people worsened. In the words of Dr. Ouk Makara, former director of the Cambodian Agricultural Research and Development Institute:

Their goal was to obtain only one social class, the farmer social class. There were no more teachers, students, doctors, any intellectuals or experts remaining; only farmers.⁹

Failures of the Khmer Rouge:

The Khmer Rouge would never attain its lofty goals. Instead, the actions led to the utter devastation of the country. This failure can be traced back to several mistakes in strategy and execution. Firstly, the Khmer Rouge disregarded the micro-climate knowledge of the farmers during the relocation of people to the farms. Cambodia had over 750 unique seed variants at the time, each adapted to specific micro-climates over generations.¹⁰ This was particularly true for the Tonle Sap region, one of Cambodia's most productive regions, which relied heavily on deep rice varieties that grew tall as the swell of Tonle Sap increased each year during the rainy season. Failing to recognize the importance of strain height to the success of the region, the Khmer Rouge outlawed tall rice varieties. As a result, one of Cambodia's most productive regions experienced complete crop failure.

Additionally, the Khmer Rouge instituted a relocation policy that completely undermined all of the local expertise that farmers rely on to grow successful crops. Not only did the regime expect inexperienced urbanites to farm, they shuffled experienced farmers around geographically. All local knowledge was lost and rice yields suffered greatly.

⁹ Quote from Dr. Ouk Makara, the former Director of CARDI, in an interview with Garrett Berghoff

¹⁰ http://books.irri.org/Cambodia_IRRI_brochure.pdf

Remaining ignorant to the importance of regional biodiversity, the Khmer Rouge also failed to recognize the importance of local rice strains. Instead, they favored unsuitable imports from China, which failed in the Cambodian environment.

Finally, the irrigation systems inspired by Angkor attempted to radically change the current geography of Cambodia but failed on multiple fronts. With the majority of the population forced to work in fields, there was a shortage of engineers which led to complete failure of most of these irrigation systems. The amalgamation of failures led to Cambodia dramatically falling short of the desired 3 ton/hectare goal set by the Khmer Rouge.¹¹ The Cambodian people were left to starve as rice was requisitioned to support military operations and personnel. The Khmer Rouge even sold surpluses to fund military and regime endeavors while the general public endured one of the worst famines in modern history.

Fall of the Khmer Rouge

As malnutrition turned into widespread famine during the five-year reign and dead bodies began to pile up, starvation became so prevalent that those suffering resorted to eating the seeds of rice. Without seeds, there was little chance to stockpile the crop year to year, leading to further depletion. As the regime began to crumble, the agricultural sector was in disarray. Cambodia lost a great number of native rice strains, and the country was crippled by hunger. The compounding nature of these problems is summarized by IRRI's former representative in Cambodia, Dr. Buyung Hadi:

There was a deficit of seeds available in the country, both in terms of supply and variety. Without seeds, how can you grow food? Without multiple varieties, how can you breed the ones that work best for your agroecosystem against different challenges?¹²

Meanwhile, Vietnam saw the growing humanitarian crisis on their western border and decided to act. On January 7, 1979, the Vietnamese military overtook Phnom Penh. The Khmer Rouge fell from power shortly after, but the damage was already done. Over 2 million people died at the hands of the Khmer Rouge from starvation or murder.¹³ Over 20% of Cambodia's population had perished within five years.

Rebuilding After Devastation

The mistakes made by the Khmer Rouge regime would haunt Cambodia long after it fell from power. Pol Pot held mass executions of Cambodia's educated citizens and, as a result, few experts survived to aid in the rebuilding of the country's agricultural sector. Of the estimated 400 agricultural scientists living in Cambodia before the genocide, only 40 survived to aid in rebuilding the country. This lack of institutional knowledge combined with poor remaining rice quality led to chronic rice shortages and low harvesting yields. Farmers had no fertilizers, no technology, and unsuitable rice varieties. The country plunged further into famine, and hundreds of thousands of people became refugees. Now an internationally recognized crisis, food needed to be flown in from abroad to prevent further starvation and mass deaths. However, communist Vietnam's presence in this transition of power dissuaded many Western countries from assisting Cambodia. Additionally, Cambodia had not seen the fruits of the Green Revolution that took place in neighboring countries, as the disruption of war and dictatorship created a highly unstable work environment. The country could not rebuild on its own and was desperate for international assistance.

¹¹ Cramb, Rob: *White Gold*, 2020

¹² Quote from Buyung Hadi, the former IRRI country representative for Cambodia, in an interview with Garrett Berghoff

¹³ Genocide, Revolution, and starvation under the Khmer Rouge.

International Cooperation: IRRI and CIAP

The International Rice Research Institute—or IRRI—was established in the 1960s in response to the insufficiency of Southeast Asian agricultural systems to cope with massive population growth. IRRI is an international entity dedicated to abolishing hunger and poverty among people and populations that depend on rice-based agri-food systems through cooperation with local people. With Cambodia reeling from the revolution and facing internal turmoil, IRRI played a crucial role in the rehabilitation of Cambodia's rice sector. Agricultural development researcher Glenn Denning summarizes the need for local involvement in rehabilitation efforts:

You couldn't transfer technologies from Europe or the United States expecting they would work in the Philippines or Cambodia. You actually had to develop the technologies locally; you had to develop them in environments where they would be used. IRRI was one of the first centers for this development.¹⁴

In the mid-1980s, Indian agricultural scientist MS Swaminathan became the Director-General of IRRI. He recognized Cambodia's dire state and initiated discussions with the Cambodian Prime Minister, Hun Sen, to revitalize the agricultural sector of the country. He proposed a program to supply Cambodia with the technological and scientific knowledge required to rebuild the country's agricultural sector.¹⁵ Swaminathan conducted discrete lobbying with the Australian government, understanding Australia's desire to bring stability to Cambodia and greater Southeast Asia. Bringing together these geographically distinct countries, Swaminathan was able to create a pact between Australian Prime Minister Bill Harden and the Government of Cambodia.

The partnership was labeled the Cambodia-IRRI-Australia Project (CIAP), and the coalition worked diligently to bring stability to Cambodia and to reinvigorate the production of the country's most valuable commodity. This work would be difficult; they were starting with nothing. But the IRRI researchers were up to the task. As Glenn Denning states:

It wasn't specifically and totally focused on Cambodia. It was focused on the region, and the governments of Vietnam and Laos were already recognized internationally; Cambodia was not. Under this umbrella of the IRRI Indochina project, we created this big Cambodia component, and we were able to get started. That's how we were able to start to train people, start to bring some technical experts to the country.¹⁶

Although the formal compact between IRRI and the Cambodian Ministry of Agriculture, Forestry, and Fisheries wasn't solidified until 1986, IRRI made astute decisions in the prior decade that allowed for a full-scale reintroduction of key rice types to Cambodia. In 1972, IRRI foresaw the looming instability in Cambodia and made the vital choice to begin collecting germplasms of different rice varieties throughout the countryside. Between December 1972 and January 1973, IRRI successfully gathered samples from each of Cambodia's 766 rice varieties, conserving Cambodia's rice diversity in their International Rice Genebank located in the Philippines.¹⁷ Although IRRI pulled out of Cambodia during the reign of the Khmer Rouge, this forethought enabled them, along with support from the Australian government, to help Cambodia on its road to recovery after the end of the Khmer Rouge's reign. Through the repatriation of all 766 rice varieties stored in their gene bank, IRRI's prior work served as the primary catalyst to rebuild Cambodia.

¹⁴ Glenn Denning in an interview with Adam Stepan

¹⁵ Denning, Glenn: *Fostering International Collaboration for food security and sustainable development: a personal perspective of M.S. Swaminathan's vision, impact and legacy for humanity* Current Science, 2015

¹⁶ Glenn Denning in an interview with Adam Stepan

¹⁷ <https://www.irri.org/where-we-work/countries/cambodia>

Rebuilding required more than just the repatriation of seeds, though. The rice supply deficiency persisted in the early 1980s. To begin bolstering the productivity of Cambodian rice, CIAP slowly began to breed strains that produce higher yields and are more climate-resistant. As a significant deficit of technical and local agricultural knowledge still existed, CIAP initiated a training campaign to re-establish the Cambodian institutional knowledge wiped out during the Khmer Rouge regime. By 2001, CIAP trained 1,700 new Cambodian agricultural scientists.¹⁸ These scientists specialized in issues salient to Cambodia specifically, studying the growth of rice in wet seasons, dry seasons, flooded areas, and productive regions near Tonle Sap and the Mekong Delta. Going along with this local specialization, CIAP generated rice varieties for both wet and dry season production. Farmer education programs commenced throughout the country, and newly acquired techniques adapted to Cambodia's varying landscapes stimulated more production and higher yields.

The greatest beneficiaries of these programs were the rice farmers who had lost much during the reign of the Khmer Rouge. Describing the impact of these aid programs, genocide survivor and present-day farmer Lee Thhert stated:

In farming, the most difficult barrier is technical ignorance. Before IRRI, we farmed with no technical aid. Our seed was of poor quality. After receiving rice varieties and techniques from IRRI and CARDI, our farmers were able to have a better livelihood.¹⁹

Cambodia's National Solution

The reconstruction of Cambodia gained pace during the 1990s as CIAP's efforts came to fruition. The economy boomed as crucial economic reforms took place and Cambodia's relationship with the western world improved. 1993 saw the induction of the Royal Government of Cambodia after a UN-supervised election, and soon foreign investment in Cambodia increased.²⁰ Cambodia saw rapid economic growth beginning in mid-1995 which continued till 2019.²¹ In 1995 they observed the first year of rice production capable of feeding the whole country. Yet farmers' production exceeded simple self-sufficiency, producing a surplus of 400,000 tons of rice for export to stimulate the economy. This long-term growth would not have been possible if Cambodia had remained reliant on foreign governments and international organizations, though. To truly achieve these successes, they needed a national solution that put the fate of Cambodia's economic and agricultural future finally into the hands of Cambodians.

As successful as CIAP proved to be, it was Swaminathan's strong belief that a country needs to be given the agency to rebuild with its own knowledge, resources, and institutions. As mentioned by Denning, "[Swaminathan] appreciated the necessity of strong national research infrastructure."²² This sentiment guided Swaminathan's operations in Cambodia, directing CIAP's energy toward the creation of a national entity for conducting and implementing agricultural research for rice in Cambodia. With Swaminathan's guidance, Cambodia established its first research center, the Cambodian Agricultural Research and Development Institute (CARDI), in mid-1999.²³

Achieving National Autonomy Through CARDI

Many of those who came to have an active role in Cambodian agricultural self-reliance through CARDI began their training with CIAP. Dr. Ouk Makara was one of the many whom CIAP trained before he

¹⁸ Denning, Glenn: *"Fostering International Collaboration"*, 2015

¹⁹ Lee Thhert in an interview with Garrett Berghoff

²⁰ Cramb, Rob: *White Gold*, 2020

²¹ <https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=KH>

²² Denning, Glenn: *"Fostering International Collaboration"*, 2015

²³ <http://www.cardi.org.kh/?page=detail&menu1=6&ctype=article&id=6&lg=en>

furthered his education at the University of Queensland, Australia. After receiving a Ph.D. in Agricultural Sciences, Dr. Makara became the director of CARDI, leading the country's scientific endeavors to improve rice productivity and resilience through innovative rice breeding techniques. During his tenure, he and his team bred a total of 44 rice varieties which are used in Cambodia today.²⁴ Many of these varieties have become lucrative, including certain aromatic varieties like Phka Rumduol, which proved immensely successful in the international market. Because of Dr. Makara's breeding programs, Phka Rumduol has since won several awards for being the world's finest and most flavorful rice. Yung Yai, a farmer and teacher personally impacted by Dr. Makara's successes, stated:

Dr. Makara was the one who changed rice varieties in Cambodia; before, we used what we had from our grandparents. We saw great results and a difference in both the quantity and quality of the seed from CARDI.²⁵

Establishing and supporting national entities such as CARDI is part of IRRI's philosophy because building the capacity for a country's independent research team has several benefits. CARDI allows Cambodia to operate independently and to continue the work of breeding, researching and mechanizing rice production to fulfill the country's needs. The creation of CARDI was the most sustainable approach to agricultural development in Cambodia because it has the advantage of being fine-tuned to the needs of the country and the people.

Although CARDI's scientific efforts provided versatility and higher yields for rice production, farmers' adoption of new varieties did not occur overnight. Not only does introducing new varieties back into the ecosystem take time, but training farmers in the proper techniques to grow these varieties and ensuring all necessary steps are taken throughout the production process requires a great deal of collaborative effort and willing participation from all parties involved. Because of these difficulties, only 17% of the country's farmers had accepted the rice varieties released by CARDI by 2003, its fourth year of operation. However, due to the new varieties' high success both in terms of improved quality and productivity rates over traditional varieties, early adopters saw tangible results, and word began to spread. In the words of Lee Thhert:

More farmers began to recognize the purity of the rice coming from CARDI. Clients began offering more money, so we switched from the traditional varieties of our ancestors to the new varieties.²⁶

IRRI and CARDI continued their educational campaigns, aiding more farmers in the transition process. While traditional methods of farming had been an integral part of the Khmer culture, farming with scientifically bred strains of rice now allowed farmers to have more success. The benefits of a scientific approach to farming became even more pronounced, as CARDI and IRRI's hardier varieties allowed for more flexibility in an erratic climate compared to unpredictable traditional farming tactics. On these benefits, Cambodian farmer Yeam Savoth expressed praise for the new techniques:

I have been guided by IRRI ever since I was introduced to them. As I followed their techniques and suggestions, I have become more successful. I have received higher yields, earning more profits to support my family.²⁷

Cambodia's Success Today

²⁴ *ibid.*

²⁵ Quote from farmer Yung Yai in interview with Garrett Berghoff.

²⁶ Quote from Lee Thhert in interview with Garrett Berghoff.

²⁷ Quote from Yeam Savoth in Interview with Garrett Berghoff.

Working with support from international organizations, the Khmer people have redefined the narrative of Cambodia. The country has seen miraculous development and the people have shown incredible resilience in building back after the terror and destruction of the Khmer Rouge reign. Cambodia has progressed from a war-torn state ravaged by severe famine to a period of self-sufficiency, finally becoming a surplus rice exporter. Average yields have nearly tripled since the inception of CIAP. Extensification slowed down in the 21st century, but production has boomed; harvested land increased from 1.9 million hectares in 2000 to 3 million hectares and production has increased from 4 million tons in 2000 to 10.9 million tons today.²⁸

IRRI and CARDI continue to work collaboratively to support the people of Cambodia. CARDI focuses primarily on rice adaptation and breeding, and IRRI plays a more supportive role for both CARDI and rural farmers in Cambodia. CARDI sets an agenda for their vision of a more prosperous rice economy, and IRRI reviews CARDI's work plan, offering technological or methodological solutions to make their vision attainable. IRRI approaches CARDI with new technology and strategies to see if they are interested in adopting them. This has been especially effective for IRRI's innovative work with pest management systems, creating new methods to prevent and mitigate pests' ability to destroy large portions of crops.

IRRI continues to educate farmers on pest management, pesticide usage, bacterial composition in soil (soil quality), and technology. Ignorance about the adverse health impacts of pesticides is a particular problem that IRRI is helping to rectify by educating farmers on proper pesticide usage. These organizations also encourage cooperation amongst farmers, who work together to help educate one another. If one farmer receives a seed from IRRI that proves to be quite effective in a particular area of Cambodia, they will share this knowledge with others. Furthermore, farmers with previous connections to IRRI can introduce other farmers who might not be affiliated. On this collaborative spirit, community leader and farmer Munn Moeun said:

If any farmers are looking for seeds, we report this information to IRRI, and they send the seeds from CARDI. If we ever need any materials or tools to separate different varieties, we contact them, and they provide it.²⁹

Problems of Tomorrow: Climate Change

The work of CARDI and IRRI have helped Cambodia rebuild from past disasters, but their work is far from complete. The 21st Century will bring new challenges to agricultural practices, especially due to climate change. With geographical and societal landscapes rapidly evolving, CARDI will use IRRI's support to build a new future for Cambodia.

The impact of climate change on Cambodia cannot be overstated. One season of unpredictable weather is enough to destroy entire fields of crops and leave Cambodia's smallholder farmers in crisis. With a steady climate, the use of a single rice variety can often suffice to support a population. But when the climate becomes erratic, a larger arsenal of options is required. With this variety comes added complexity. Farmers need the knowledge to understand which option to use during any given season, and which agronomic practices should accompany the respective implemented option. These choices directly impact farmers' livelihoods because any stress to the rice-growing ecosystem will impact their yield. Severe drought can completely destroy a season's crop, leading to heavy debts for farmers as they take loans to support their families in times of crisis. These crises then compound, forcing mass migration as farmers flee to Vietnam and Thailand in search of more stable incomes. The most recent drought of 2016 was the most damaging the country has seen in decades. River levels depleted 30-50% leading to increased salinity levels in the water. These then damaged and destroyed many rice strains not resistant to salinity,

²⁸ <http://www.fao.org/faostat/en/#data/QC/visualize>

²⁹ Quote from Munn Moeun in interview with Garrett Berghoff

a problem that can be avoided with more access to more robust strains. Even so, lack of rain and irrigation killed many crops. The drought directly affected an estimated 2.5 million people.³⁰

Local institutions are essential for addressing the threat of climate change and its subsequent ripple effects. CARDI and IRRI both actively work with scientists to diligently provide the most successful mitigating strategies possible with the resources available. The sheer unpredictability of weather patterns can leave scientists and farmers guessing, making decisions about what problems to allocate precious time and resources toward difficult, whether that is creating drought-resistant or flood-resistant varieties.

There is still hope, though. CARDI has already created the necessary drought-resistant varieties, all without losing the marketable aromatic quality of rice, as seen in award-winning Phka Rumduol. Because of drought's compounding environmental problems, it is not sufficient to merely create a strain that requires less water; rice variations more resistant to salinity are also being produced in response to the droughts. Additionally, CARDI has worked to execute strains with a shorter lifespan because the shorter the time it takes rice to grow, the less water the crop requires. Dr. Buyung Hadi explains the necessity of combating climate change, especially for poor farmers, thusly:

Climate change is our biggest challenge, as we have seen the last five years. Last year (2019), rain came very late, it was one of the worst droughts in the last decade – right now it's still very dry for agricultural land. And two years before that, it was not drought, it was flood. All of these extreme events will continue providing challenges for farmers, especially for smallholder farmers. The poorer ones will be the hardest hit by these changes. IRRI can provide technologies that can help smallholder farmers to adapt to these extremes and to mitigate the risks.³¹

Solutions of Tomorrow: Technology

Much of the local solution to these 21st Century problems lies within technological development. As we have seen through the mechanization of agriculture in the western world, technology can provide immense benefit to many aspects of rural farming. Modern irrigation is especially necessary for helping Cambodia mitigate the disastrous effects of climate change. Precision agriculture also preserves the livelihood of farmers, as it requires fewer materials and time than traditional agriculture, leaving resources and time for other tasks. Production can also greatly increase with mechanization, as less crop is lost in the process and crops can be harvested at significantly faster rates.

Irrigation:

The question of irrigation often comes into the conversation when discussing modern solutions for Cambodia's climate predicament. Unfortunately, irrigation is largely underfunded in Cambodia, and less than 10% of Cambodia's arable land is irrigated during the dry season.³² Under normal climate conditions, this is not an issue, but the erratic climate seen in recent years leads to much uncertainty. Without extensive irrigation infrastructure, Cambodian farmers cannot control the flow of water to their crops in the event of a drought. The necessity for irrigation does not just come from climate change, though. The construction of hydroelectric dams up the Mekong River disrupts the flow of water into Tonle Sap, a vital organ of Cambodia's ecological composition and a primary supply of water for rice production. Seasonal variations in precipitation, coupled with an inability to predict the subsequent year's weather pattern, leaves both farmers and scientists guessing what challenges will need to be tackled and how to prepare.

³⁰ <https://opendevelopmentcambodia.net/topics/drought/>

³¹ Quote from Dr. Buyung Hadi in interview with Garrett Berghoff

³² Cramb, Rob: *White Gold*, 2020

As important as irrigation is, CARDI does not have the resources to develop irrigation infrastructure in Cambodia. However, the rice strains created in their labs still work as an alternative solution to constant water flows. Many rice strains created during the Green Revolution rely on frequent irrigation— systems that are much more common in neighboring Thailand and Vietnam. CARDI thus operates in a different ecosystem, one which makes the creation of drought-resistant rice varieties far more important. CARDI has worked on this problem for decades, and since their induction has bred for strains resistant to drought, flood, heat, and disease.

Mechanization:

Mechanization is another solution to the modern problems facing Cambodia. While the private sector and government play a role in the continued technological development of Cambodia, IRRI and CARDI have also adopted new strategies to incorporate technology and mechanization. Scientists at CARDI, like Dr. Ponh Oudam, are working on the creation of machines adapted to Cambodia's specific regional climates to ensure the health and safety of farmers, reduce labor requirements, and provide more precise application of pesticide administration. All of these reduce the likelihood of wasted resources. IRRI has recognized several other uses for technology and has begun strategizing the path forward for its implementation.

Through remote sensing tech and GIS, we are able to now map rice and model their situation, their condition, whether they are healthy, drought stressed, flood stressed. And we can do this at the whole country level. We are able to plan for trade because we are able to model the potential yield for the whole country using this technology.³³

Still, it is field-level technologies that provide the best solution to a shortage of labor. Machines allow farmers to manage their farmland without the need for as much human assistance. This is especially helpful because many Cambodian parents rely on their children for help farming. However, like most parents, farmers in Cambodia wish for a better life for their children than the grueling days in the rice fields where rewards don't always match the painstaking effort put in. Today, it is common for parents to encourage their children to educate themselves and earn a better living in the cities. Despite the appeal, this can create a labor shortage, as farmers no longer have the same familial support to assist with the planting, harvesting, and selling of rice. Mechanization thus provides the freedom for children to pursue higher education and a better life.

Strength in Numbers: A Unified Front for Farmers' Livelihoods

Farming is not just about production and output; it doubles as a business and a deeply personal source of livelihood for a vast percentage of Cambodia's citizens. Thus, learning how to properly conduct business is just as important as scientific literacy for farmers in modern-day Cambodia. Before 1993, Cambodia operated with a collective market controlled by the government during a period of rebuilding. In 1993, they transitioned to a free market that allowed farmers to sell their products as individuals and purchase equipment from international sources. This free market still operates today, but independent farmers are finding it more and more difficult to find fair pricing within it. Inequality among farmers is on the rise, with the average size of small farms decreasing even as medium and large farms swell enormously. Per unit profitability has increased for the industry overall, but smallholder farmers—the country's poorest—remain at risk.

To face this problem head-on, small farmers are embracing a unified approach to market dealings. Community leaders are summoning farmers from their respective regions, while IRRI helps coordinate community groups that educate farmers on their rights and capabilities. Smallholder farmers are finding success in numbers, with a unified front allowing for effective price-setting and negotiation. This is necessary because contracts set by rice milling agencies that attempt to squeeze smallholder farmers out

³³ Quote from Dr. Ponh Oudam in interview with Garrett Berghoff

of their profit margins have less coercive power when confronted by a group working collectively. A sense of community gives farmers a more confident voice to ensure a decent livelihood. While forced top-down collectivization from the Khmer Rouge destroyed the lives and livelihoods of millions of Cambodians, voluntary grassroots collective action may now be enough to save it. Munn Moeun has been particularly impacted by this new community mindset:

Before, we did not know how to work together as a community. Once farmers harvest their yields, they sell directly to a middleman, and the price is set by the middlemen. We decided to come together as a collective. Now when we need to sell rice, we discuss as a group to set the price. Unless they agree with our price, they cannot buy our rice.³⁴

Conclusion

Cambodia has come a long way since the desolation of the 20th century. The country's ability to regrow from such poverty and destruction is an inspiring story of resilience, cooperation, and innovation in the face of adversity. The repatriation of rice strains, leading to the eventual regrowth of the country, is one of the most successful stories of gene conservation to date. It serves as a model for the importance of continuing this work today on a global scale.

Cambodia has also shown us the joint importance of international cooperation and strong national institutions. Through the intervention of the IRRI, the formation of CIAP and CARDI, it is clear how investments in local expertise yield the best and most sustained results.

Cambodia continues to tackle the challenges of the 21st century by strengthening local capacity, bolstering local partnerships, and making its presence known in Southeast Asia. The Vietnam War and the subsequent genocide left Cambodia crippled as their neighbors reaped the benefits of the Green Revolution, but Cambodia finally shows continual promise in the 21st century with ceaseless innovation and dedication from farmers and scientists alike. Cooperatives provide farmers with additional agency moving forward as the global market makes smallholder farming less prosperous, and CARDI and IRRI continue to innovate with the assistance of technology. This work will be essential for the continuous need to fight the effects of climate change.

³⁴ Quote from Munn Moeun in interview with Garrett Berghoff