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The Plight of the Rural Thai Farmers

Agriculture continues to be the fundamental sustainable element of the human species since the inception of civilization. Agriculture's historical importance is underlined as a massive force in the movement of people, the catalyst of wars, and the significance of international commerce. These forces are held in check by the continued perseverance of farmers to improve crops, and produce more on the land they have. Improvements in agriculture are continuous; they diversify and enhance the produce we consume. The earliest civilizations pioneered plant husbandry, crossing crops with desired traits to produce improved varieties. Similar methods exist today, forming the basis of many of the world's agricultural altercations. Rapid technological advancements enable developed countries to expand their repertoire of agronomic techniques; but less developed nations, with exponential population growth rates, have yet to reach as high a level of scientific progress. The disparity between agronomic level and immensity of population is characterized in several Southeast Asian nations. Thailand in particular suffers from this predicament; the burgeoning economy is struggling to find an acceptable medium between industrialized and agrarian societies. Contrasting viewpoints give rise to issues that threaten Thailand's national food security. Debates over food security are increasing as industry enters into elevated conflict with the agrarian lifestyle practiced by many Thai farmers. The competition requires measures enacted to ensure adequate food for Thailand’s population. The implementation of advanced biotechnologies, can increase the yield and nutritional value of the country’s staples, convey resistance to disease and insect pests, and mitigate other adverse environmental issues, which will bestow an increase in the sustainability of Thailand's population.

Civilizations are built upon the hard work and dedication of people driven by the desire to succeed; their ingenuity provides success in the face of failure. The majority of rural Thai farmers live in the country’s northern province. The Northeastern province lags the farthest behind in both agricultural productivity and socio-economic advancement (Gibson). Poor families suffer from disconnects between family size and farm production capabilities, preventing the achievement of adequate food production. Rural farms are typically 4.04 hectares, while the average Northeast Thai family has 4.1 people (National Study: Thailand; Census 2000). In small families, between two and three able bodied workers tend crops, but most are past their prime (Od-ompanich). Often the poorest farmers will have families of five to six members to provide greater help on the farm. However, with larger families, more mouths to feed places excess stress on the land. The majority of farming families grow two types of crops: crops for commercial sale (particularly to the lowland plains) and crops for on farm consumption. Rice is generally the staple of subsistence farmers. For many farmers, harvested rice provides nearly all the family’s carbohydrate intake, because of no feasible economic means to purchase or transport other food products. Besides raising cereals for personal consumption, farmers grow a variety of other plants to support themselves economically and nutritionally. Corn is grown in rural areas as fodder for animals, such as swine and poultry, which supplement the Thai's rice diet by providing crucial amino acids. Additionally, some Thai farmers plant a variety of fruits and vegetables to increase meal variety, supply vital nutrients and sell surplus in local markets or to Thailand’s growing agribusiness. Tropical fruits such as oranges, lychee, langgan, and papaya are sold to the lower plains and urban areas that are incapable of growing them in vast quantities. Despite the large percentage of the national economy devoted to agriculture, the practices have not progressed as rapidly among rural farmers as they have among agribusiness tenants. Most rural farmers require the use of physical labor or draft animals to produce crops. Agricultural mechanization for farmers is limited; typically only small walk-behind tractors are available. Manual labor of Northeastern Thailand is a function of the small plots of land and low incomes of subsistence farmers. In addition to manual crop sowing, harvest and post-harvest procedures are often completed by hand. Commonly rice kernels are extracted through hand thrashing; however, occasionally a village’s more profitable families will band together to rent a mechanical thrasher (Gibson). Planting and harvesting methods prove to be the most insurmountable obstacles in the improvement of Thai farming capabilities. Without a more mechanized approach, farmers are limited by their family size as to the amount of land they can cultivate each season. Additionally, the lack of defined and well placed transportation routes decreases the availability of markets rural farmers can sell perishable crops to. These restrictions are part of rural life in Thailand, preventing farmers from improving their economic situation through their own mechanisms, passing the responsibility to more developed countries to provide farmers with the ability to enhance their lives.

While rice dominates the distribution of crops among rural Thai farmers, the choice of rice variety plays a large role in the farmers' ability to produce yields that generate additional income. Large percentages of rural subsistence farmers rely upon native varieties which they collect seed from. Often they oppose the use of genetically engineered and Green Revolution varieties because of the additional requirements associated with the improved lines. Superior yield lines often rely upon additions of large quantities of inorganically synthesized fertilizers (Od-ompanich). These accessory requirements dramatically increase the costs of land cultivation, and cannot always be reabsorbed during the sale of excess crop. To combat this issue, rice lines have to be developed to use nutrients more efficiently (AFP). Nitrogen is the most common of the inorganic fertilizers applied to Green Revolution varieties; but typically they are either not readily available or cost prohibitive. Recent developments indicate that certain nitrogen fixing bacteria, such as *Gluconacetobacter diazotrophicus* and *Herbaspirillum rubrisubalbicans*, can be induced to colonize the inter-cellular spaces of rice roots and fix nitrogen to forms that rice can absorb into its cellular structure in lieu of ammonia and nitrate fertilizers (Cummings). These modified plants would help create a more sustainable agricultural system. Enabling farmers to remain in one location longer, without resorting to slash and burn clearing to obtain nutrient rich land. Additionally, a symbiotic relationship would allow the farmer to plant cereal crops more continuously, reducing the need to leave fields fallow or grow legumes for the sole purpose of nitrogen fixation.

Rice is typically grown under one of two cropping methods: upland dry rice farming or lowland wet farming. Rice species grown with dry land farming often encounter periods of drought stress because of water scarcity resulting from competition between industrial and agricultural sectors (IFAD). In order to increase plant hardiness during drought conditions, researchers over-expressed the late embryogenesis abundant proteins of certain rice strains, which displayed a corresponding yield increase among the modified plants under drought conditions (Xiao). The heightened resistance to drought stresses enables farmers to obtain nominal yields in regions that suffer from a chronic lack in moisture. In addition to environmental hardships, farmers must also deal with disease and viral damage to crops. The Rice Tungro disease is one of the most endemic diseases, causing over a billion dollars worth of damage to rice crops worldwide. The effects on subsistence farmers are much more devastating than mere lost production value. Rice Tungro disease is a co-infection of two unrelated viruses, Rice Tungro Spherical Virus and Rice Tungro Bacilliform Virus. The Bacilliform Virus causes almost all of the symptoms, stunted and discolored growth, however in infection cannot occur without the simultaneous infection of the Spherical Virus. Researchers, in an effort to curb the virus's disastrous effects, discovered that an overproduction of two rice's transcription factors, that regulates the expression of the Bacilliform Viral promoters in addition to normal plant development, causes a decrease in symptoms after exposure to the Rice Tungro Bacilliform Virus. Additionally, the stimulation of transcription factor production demonstrated no adverse effects to normal plant development (Dai). Resistance to viral infections allows the possibility of eradication of a source of despair on Thailand's rural farms.

Nutritional enhancement of foods commonly consumed by the world's poorest provides the means to reduce subsistence farmers overall malnutrition. Researchers from the International Rice Research Institute biofortified a high producing *indica* rice line to accumulate higher levels of iron and zinc in the seed's germplasm (Vasconcelos). This is vital because brown rice, or unpolished rice, is rarely ingested by Thai consumers (Gibson). The polishing process, used to prevent the grain from turning rancid after harvest (Runge), removes a vast quantity of micronutrients stored in the outer layers as detritus. Increased iron levels in biofortified rice help to alleviate iron anemia deficiency, a condition which causes decreased erythrocyte size, and a decreased in the level of iron binding to the glycoprotein transferrin (Vasconcelos; Internet). These conditions lead to chronic illnesses, autoimmune diseases, neoplasia resulting in uncoordinated new cell growth, and chronic inflammation (Internet). Thus genetic biofortification of crops improves individual and collective personal health. These improvements are often incorporated into high performing rice lines that make efficient use of soil nutrients to offset the rather low soil solubility of many of the metals, including zinc (Vasconcelos; Cakmak). Despite that much of the rural farmers' caloritic intake and necessary nutrients come from rice, other crops must be enhanced to provide complete nourishment. Recent research into *Brassica rapa,* commonly known as Chinese cabbage, highlights its potential for increased accumulation of zinc. Zinc is critical to human health since approximately 10% of all human proteins rely upon zinc binding sites, yet at least 68% of up to 95% of the Southeast Asian populations are at risk for zinc deficiencies. The complex nature of *B. rapa*'s mineral uptake system requires a greater amount of modification, compared to many bioengineered plants, to design a system that safely stores zinc in the leaves. The majority of minerals are stored in the vegatative leaves of the plants. This makes *B. rapa* an ideal crop for enhancement since the leaves are consumed, which provides the greatest boost to the human zinc uptake (Feagley). Safe storage of beneficial minerals is paramount because several mineral transport proteins in the root cells transport multiple ions, potentially leading to an over accumulation of toxic minerals. Despite the complexity of the task, current research indicates high potential for the modification of *B. rapa* to allow the increased tolerances to and accumulation of minerals (Wu). The enhancement of Chinese cabbage and rice lines provide additional nutrition to large numbers of poor and malnourished individuals that previously had none.

To provide economic prosperity to the mountain farmers of Thailand, more has to be done than improve the basic nutrient supply. Farmers need access to a variety of crops that will support them in their endeavor to enhance their economic position. This means the enhancement of fruits and vegetables as alternate sources of nutrition must be embraced. Papaya, *Carica papaya*, is one of the most nutritious fruits available to the subsistence farmers. One serving of papaya (about a quarter of a full grown fruit) provides 133% of an individual's daily Vitamin C intake, and 33% of the recommended Vitamin A intake, both which increase iron uptake, helping to mitigate two of the three largest micronutrient deficiencies in the world's poorest farmers (Davidson). In addition to large health benefits, papaya also provides economic vitality through the *papin* protein used in a variety of industrial applications. While the poorest of Thailand's subsistence families rely upon papaya to provide supplemental nutrition, their reliance is shattered yearly by the Papaya Ringspot Virus. Papaya Ringspot Virus adversely affects the photosynthetic capacity of the papaya trees, resulting in drastic damages ranging from blemished to inedible fruit, ultimately resulting in total plant death. Despite no natural resistance, using transgenic techniques researchers conveyed resistance through viral coat proteins sans the virus (ASBPII). Despite the success and praise garnered in locations such as Hawaii, governmental instability and radical political groups in Thailand prevent the testing and use of any new genetically engineered organisms. The ban, enacted in the early 2000's, is still in affect despite the desperately needed presence of genetically engineered papaya, particularly in the many areas with 100% (Davidson). Rural farmers in addition to papaya groves often plant small vegetable gardens, commonly with Chinese cabbage. Chinese cabbage suffers from constant assault by bacterial diseases. Bacterial soft-rot, caused by *Pectobacterium carotovorum,* damages the cabbages of rural Thai farmers, presenting them with inedible food, and a loss on investment. Through the development of transgenic cabbage, researchers have shown an increased resistance to moderate exposures of *P. carotovorum* (Jung). Transgenic disease resistant *Brassica rapa*, combined with enhanced zinc accumulation, has the potential to consistently provide essential minerals to malnourished individuals. The modification of vegetables and fruit to resist endemic disease creates the foundation of a secure food supply.

Besides correcting and enhancing individual issues that afflict particular species, a broader look must be taken to envision the ways that crop biology can develop a sustainable agricultural system. This is sustainable agriculture systems are critical to Thailand's improvements to become a leader in productivity, and to achieve developed country status. Currently much of Thailand’s success and self-sufficiency have not come from increased productivity of current land, instead from increasing the total land under cultivation. Much of the land forced into production in Thailand's rural areas is marginal at best, and is not capable of meeting the demands made by rapid use and double cropping techniques used to increase yearly output with current agronomic methods. Often impoverished farmers only have marginal land to farm; and use the land available without implementing proper techniques to control soil erosion and increase nutrient availability. Rice farmers flood paddy fields to soak the ground and provide water for the fast maturing plants. However, rather than reusing the water elsewhere, it is commonly drained; wasting water that could otherwise be utilized in an tiered irrigation system to distribute the remaining water over a broad range of utilities (Khan). The prevention of soil erosion drastically reduces the losses of surface nutrients. During the decomposition of plant material, and applications of artificial fertilizers, the nutrients slowly sink into the lower layers of humus. However, during the period of transition, rapid soil movement from irrigation or heavy rains removes many of the nutrients that have not yet permeated the soil (Ed Runge). The runoff of surface nutrients accumulates in the river basins where it can have detrimental effects on the currently productive valley areas (Roonnaphai). The complete sequestration of nutrients in a particular plot of land is an impossible task, since some nutrient loss will be inherent through the movement of micro nutrients in the lower soil layers, the same mechanisms that created the fertile river valleys (Ed Runge). Still, reducing soil run off will conserve a greater amount of nutrients than current practices allow.

Farmers often raise livestock to supplement their grain and fruit with protein. Animals, however, consume far more biomass than the farmer can obtain through consumption of livestock's products. This raises the debate between repurposing land for grazing and feed production, or continue to cultivate grains that provide a greater number of calories.  Recent studies have demonstrated that unconventional plants, such as cassava can provide protein supplements for livestock. Cassava’s foliage can replace protein supplements in cattle, goat, and swine diets due to the equivalent of 4 metric tons of protein per hectare are present in leaves when managed as perennial forage, harvesting the leaves every eight to ten weeks (Preston). In order to offset the greater nutrient draw, nutrients, especially nitrogen, must be replenished much more often than if cassava is grown for tuber production alone. The application of livestock manure to cassava plants mitigates some of its nutrient draw from the surrounding soils; however, the manure is often high in phosphorus relative to the nitrogen content (Howeler). Phosphorus present in manure is highly soluble in water and is often removed from the land, if erosion is not controlled, before microbes convert it to insoluble ions through mineralization. The net nitrogen uptake can be mitigated by intercropping cassava with plant species that store large amounts of nitrogen uptake in vegetative plant parts that are left in the field to decompose. (Waskom). Utilizing the tubers as an underground nutrient storage facility, one cassava plant can be managed as forage for approximately three years before needing to be replaced (Preston). Extracted tubers can either be sold to commercial industries for conversion into cassava products for export or processed into tapioca flour for home meals (Preston; Roonnaphai). The use of hardy plants to sustain agricultural farmland represents subsistence farmers need for access to a diverse, but economically achievable diet.

To improve environmental sustainability of agricultural systems, novel approaches must be assessed to produce sustainable environments that will continue to produce crops in the future. Nutrient leaching presents a problem to all crop varieties grown. A reduction in nutrients available prevents plants from reaching their genetic potential. In order to prevent nutrient loss, soil covers and boundary plants must be planted. Raising cassava on field perimeters forms a boundary that limits soil movement outside of the field, preventing degrading erosion. Highly capable drought resistant mechanisms allow cassava to survive where many other covers perish (Zhang). Preserving nutrients left in the soil after harvests requires the restriction of soil movement through soil cover as well as forming erosion breaks. Cassava planted on contour ridges can be utilized as an efficient erosion stopper, preventing both wind and water from removing the top layer of soil (Howler). Additionally, cover crops trap nutrients already present in the soil, increasing nutrient levels as microbes break down organic matter. Soil cover can either be achieved through crop residue or through rotations of green manures. Green manures, often legumes, are grown to fix nitrogen in the soil, then killed to allow the humus to reabsorbed the nutrients in the plant matter (Hobbs). Letting the crop residues reside on the field is a crucial aspect of squeezing all the available nutrients from a potential source. As crops mature they extract nitrogen, potassium, and carbon from the soil, and harvesting the entire plant reduces the total nutrients available. Letting the crop residues decompose into the soil allows crucial nutrients left in the plant stalks to be reused in the following years crops. The use of conservation cropping methods will limit the amount of additional artificial fertilizers that farmers will have to purchase the following year. These sustainable agricultural systems can be achieved, ensuring food production for the coming decades.

As the world enters into the 21$^{th}$ century head on, there is a clash between developed nation's desires for cleaner energy and developing nation's need for increased food security and supplies. Biofuels present a unique juncture between urban society and the chance for farmers to regain participation in the production of energy again. Biofuels are created from any manner of biomass: edible crops, oily seeds, or from crop residues. Many prominent biofuel reservoirs are currently draw upon food crops, limiting food yields. Cassava roots are currently utilized in industrial applications ranging from paper and textile to drinking alcohol additives and artificial sweeteners. The cassava requirements those uses have stayed consistent through much of the last decade; however, ethanol production from cassava roots has exploded, demanding larger quantity of roots. The yield demanded by the emerging industry can be met by the use of higher yielding varieties, distributed through cooperatives with farmers. (CIAT). However, these farmers must have access to commercial fertilizers in order to meet the nutrient requirements of large quantities of cassava plants. The use of commercial fertilizers inhibits many subsistence farmers from participating in the increase of incomes presented by the sale of a lucrative crop. While biofuel needs can be met without transitioning current arable land from food production (Gonsalves), an emphasis must be placed on subsistence farmers that their primary goal should be self sufficiency. Independence can be achieved through the incorporation of energy crops into farming methodologies, provided farmers are not distracted from immediate nutritional requirements in the pursuit of cash.

The advancement of agronomic techniques will lead to the improvement of living conditions and elevation of lifestyles of rural subsistence farmers in the poorest parts of Northeast Thailand. The development of genetically engineered crops strains allows farmers to improve their quality of life. The engineered crops allow farmers to harvest superior yields through grain yield modification, or through resistance to disease and other pests. Controlling pests that plague crops through the use of biological deterrents gives farmers a twofold advantage: the reduction of pesticides provides extra money that can be invested to diversify his holdings, and provides an innate resistance to detrimental pests. Furthermore, the biofortification of various crop species provides a broad range of nutritionally enhanced foods, that farmers and their families can readily consume. The use of marginal crops to prevent desertification and increase feed stocks enables subsistence farmers to be more productive. Advances in crop biology and agronomic techniques grant rural subsistence farmers the means through which they can become independent. Improving farmers harvest capacity allows surplus food stores to improve the physical well being of the nation’s urban poor through the diffusion of excess. The distribution of excess can only be realized through the development of markets and efficient transportation routes that enable poor farmers to easily market their goods. Thailand is a burgeoning nation whose use of advanced biotechnology applications enables farmers to reliably produce food, increasing the nation’s food security and supporting the growing population's need for sustenance.

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