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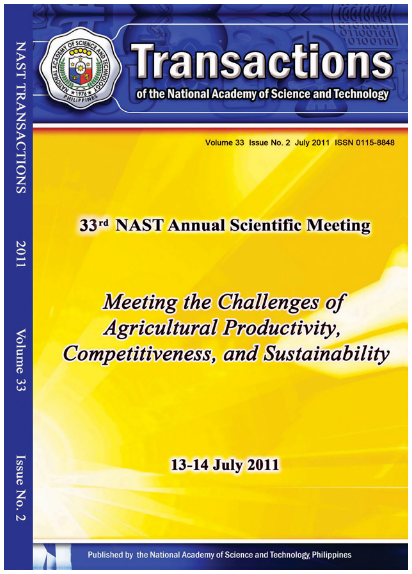

Further Intensification of Agriculture: A Must to Meet the Challenges of Agricultural Productivity, Sustainability and Competitiveness

Ruben L. Villareal[*1], Evelyn Mae Tecson-Mendoza[2], Victor B. Ella[3], Arnold R. Elepaño[3], Pompe C. Sta. Cruz[4], Rodrigo B. Badayos[4], Cezar P. Mamaril[5] and Emiliana N. Bernardo[6]

[*] Corresponding author
[1] Academician, National Academy of Science and Technology (NAST), Philippines
[2] Academician, National Academy of Science and Technology and Research Professor, UPLB
[3] Professor, College of Engineering and Agro-Industrial Technology, UPLB
[4] Professor, College of Agriculture
[5] Senior Consultant in Soil/Agronomy, Philippine Rice Research Institute
[6] Retired UPLB Professor of Entomology and UPLB-IBC member

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FURTHER INTENSIFICATION OF AGRICULTURE: A MUST TO MEET THE CHALLENGES OF AGRICULTURAL PRODUCTIVITY, SUSTAINABILITY AND COMPETITIVENESS

Ruben L. Villareal*[1], Evelyn Mae Tecson-Mendoza[2], Victor B. Ella[3], Arnold R. Elepaño[3], Pompe C. Sta. Cruz[4], Rodrigo B. Badayos[4], Cezar P. Mamaril[5] and Emiliana N. Bernardo[6]

Introduction

The Philippines faces the dauntless task of producing more and more food from less and less arable land and irrigation water. Like most of the rest of the developing world, the burgeoning population in the Philippines results in low per capita availability of arable land and fresh water for irrigation. Moreover, Philippine agriculture is faced with multifaceted challenges such as low land and labor productivity, high production cost, post production and distribution losses, high environmental and market risks to producers, low private sector interest in agriculture and degradation of ecological services. All of these contribute to low income and poverty of farmers, high food costs to consumers, deterioration of environment, and lack of competitiveness of Philippine agricultural products in the world market.

Indeed, challenges to Philippine agriculture are complex and thus require multidisciplinary, innovative strategies. All possible means to increase agricultural productivity in a sustainable manner should be utilized. This paper analyzed some key factors and issues to further intensify agriculture for productivity, sustainability and competitiveness. Specifically, we looked into land use and administration, raising cropping index, varietal improvement and agricultural biotechnology, water use efficiency, integrated nutrient management, integrated pest management and labor productivity and mechanization.

*Corresponding author
[1] Academician, National Academy of Science and Technology (NAST), Philippines
[2] Academician, National Academy of Science and Technology and Research Professor, UPLB
[3] Professor, College of Engineering and Agro-Industrial Technology, UPLB
[4] Professor, College of Agriculture
[5] Senior Consultant in Soil/Agronomy, Philippine Rice Research Institute
[6] Retired UPLB Professor of Entomology and UPLB-IBC member

Land Use and Administration

Land use planning is the practice of accounting and allocation of land resources in order to meet national requirement for food, feed and energy including sites for the needed infrastructure of the community as well as additional space to accommodate wildlife habitat. Critical to the planning process is the evaluation of land resource potential towards sustainable land utilization. With identified major soil constraints to food production such as water availability, low CEC, aluminum toxicity, vertic properties, high P fixation, shallowness and erosion risk, Philippines has barely 9.323 M hectares of arable land with a potential of supporting only the grain requirements of a population of 22.909 M, 41.559 M and 76.295 M under low, medium, and high technology input levels, respectively (Beinroth, Eswaran and Reich, 2001). The estimate does not even take into account the negative impact of climate change, extent of land degradation due to mismanagement and neglect, which can exacerbate the productivity of available arable lands for particular agricultural crops (Badayos, 2011). This available arable land translates to current land availability of only 1080 square meters for every Filipino. This very narrow land: people ratio can only get worse as Congress continues its debate on the reproductive health bill (PA 2020, 2011).

Thus, the second order of business, after finally arriving at a national consensus on family planning/population management, is appropriate governance and strong political will to halt the conversion of prime, irreplaceable farm lands into settlements, industry and other non-agricultural uses. The Comprehensive National Land Use Policy and Plan legislation is long overdue. Cadastral mapping and delineation of forestlands, protected areas and ancestral domains should be completed soonest. All LGUs must complete their local land use plans consistent with national guidelines and implement the same with rigor and firmness.

Moreover, land administration is lodged in several departments and bureaus and is therefore very fragmented, very confusing and inefficient. It is imperative therefore, to consolidate all government lands management activities under DENR. Hence, the participants of the Annual Scientific Meeting (NAST, 2011) proposed the following resolution addressed to the Office of the President and Legislative Bodies:

> "Enactment of a Comprehensive National Land Use Plan Law, Lands Administration Reform Law and the establishment of the Lands Administration Authority (LAA) under the Department of Environment and Natural Resources for an integrated, unified, synchronized system of land use planning at all levels. LAA will integrate the functions of Lands Registration Authority, Registry of Deeds, Lands Management Bureaus, Lands Management Services and National Mapping Resources Information Authority (NAMRIA)..."

In addition, the following resolution was proposed to the Department of Environment and Natural Resources (DENR) and the Department of Interior and Local Government (DILG):

> "Immediate completion of cadastral maps to delineate forestlands, protected areas and ancestral domains; and facilitating and expediting the completion by LGUs of their respective comprehensive land use plan (CLUPs) to serve as an integrating framework in the management of resources…"

Hand in hand with the governance and implementation issues, it is also imperative to train more experts in land planning, accounting and allocation of land resources in the university and in government, the LGUs/stakeholders in order to prepare them for teaching, research and practical application, respectively. Thus, this capacity building should be supported by both local and national governments.

Raising Cropping Index

Land productivity could be further improved by raising crop yields per cropping and on per unit area-basis by raising the cropping index (CI). Total annual harvested area is about 12.4 million hectares, which with a physical area of 10.3 million hectares, translates to a cropping index of 1.20. With our favorable year-round growing conditions, cropping intensity could be raised to 2 to 3 or a potential harvested area of 20.6 to 30.9 million hectares.

As a starting point, we have to look at the current CI in our crop production areas. However, current information on cropping index is limited to our agriculture data sets of crop production information such as area planted, yield per hectare and production volume per crop. In most cases (except for the monoculture cropping), these do not reflect the contribution of CI in attaining the present crop production level. Hence, increasing the CI in our agricultural lands should be done on area-basis, i. e., on properly delineated areas that will allow accounting of the various interventions directed towards increasing crop productivity.

Rice-based Cropping

Raising the CI of a rice-based cropping system from 1 to 2 can be achieved through rice double cropping ($Rice_1$-$Rice_2$) or Rice-Upland Crop (UC) cropping. Increasing CI from 2 to 3 can be achieved through Rice-UC_1-UC_2, $Rice_1$-UC-$Rice_2$ or triple rice cropping ($Rice_1$-$Rice_2$-$Rice_3$) (**Figure 1**).

Raising CI from 1 to 2. With wet season rice as the base crop, sequential planting of dry season rice ($Rice_{ws}$ - $Rice_{ds}$), or relay/sequential planting of short-duration upland crop ($Rice_{ws}$ - UC_{ds}) can be done. Raising CI from 2 to 3. With $Rice_{ws}$ - $Rice_{ds}$ as the base crops, planting of the 3^{rd} rice crop during the transition period between dry and wet seasons can be done such as $Rice_{ws}$ - $Rice_{ws\text{-}ds\ transition}$ - $Rice_{ds}$. Sequential or relay planting of short duration upland crop can also be a potential option for $Rice_{ws}$ - $Rice_{ds}$ and for $Rice_{ws}$ - UC_{ds} as base crops, thus a cropping system of $Rice_{ws}$ - $UC_{ws\text{-}ds\ transition}$ - $Rice_{ds}$, or $Rice_{ws}$ - $UC_{ws\text{-}ds\ transition}$ - UC_{ds}.

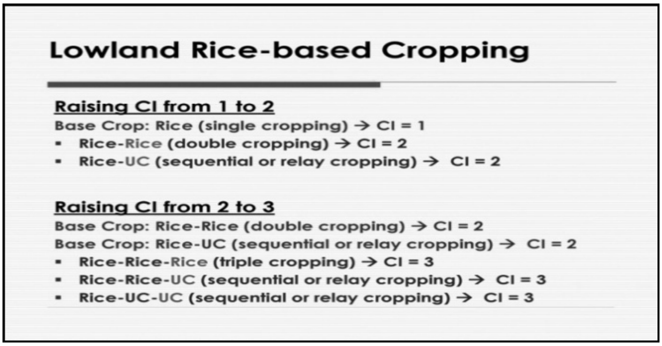


Figure 1. Raising cropping index for lowland rice-based cropping system from CI 1-2 and CI 2-3 (Sta. Cruz, 2011)

Annual Upland Crop-based Cropping

Annual upland cropping may include monoculture (e. g. corn) or multiple cropping of long-duration (6–12 mo) annuals (e. g. sugarcane, cassava) and short-duration (3 mo) annuals (grain crops, grain legumes, vegetables, etc.)

Raising the CI from 1 to 2 in annual upland crop-based cropping can be achieved through intercropping of a long-duration annual with short-duration annual ($UC_{1(LD)}$ + $UC_{2(SD)}$) or sequential cropping of two short-duration annuals ($UC_{1(SD)}$ – $UC_{2(SD)}$). With the long-duration annual as the main crop, a short duration crop can be intercropped ($UC_{l\ (LD)}$ + $UC_{2\ (SD)}$) (**Figure 2**). The short-duration crop is usually harvested before the canopy of the main crop closes. Increasing the CI from 2 to 3 can be achieved through sequential cropping of 1 crop or 3 fast-maturing upland annuals ($UC_{1(SD)}$ – $UC_{2(SD)}$ – $UC_{3(SD)}$).

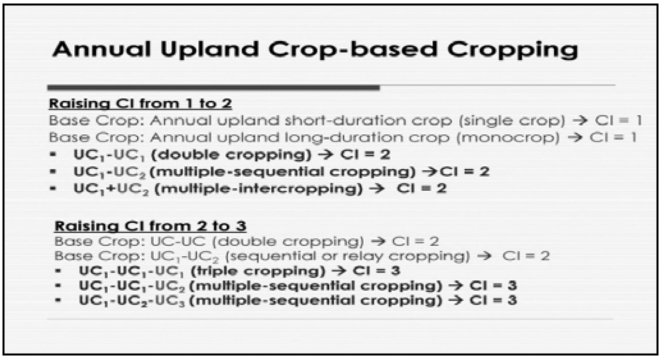


Figure 2. Raising crop index for annual upland crop-based cropping from CI 1-2 and CI 2-3 (Sta. Cruz, 2011)

Coconut- and Perennial Crop-based Cropping

Existing coconut and perennial crop-based cropping offers great potential in raising the CI from 1 to 3 or more. The multi-storey cropping has been proven to be productive in a lot of farms across the country. In coconut-based or perennial crop- based cropping, short-duration field/horticultural crops can be intercropped during the earlier stage of the main crop, while shade-loving fruit trees, vines and/or low-growing field/horticultural crops can be intercropped when the main crop is about to reach its maximum leaf area or canopy size, i.e., near canopy closure at optimum plant spacing (**Figure 3**).

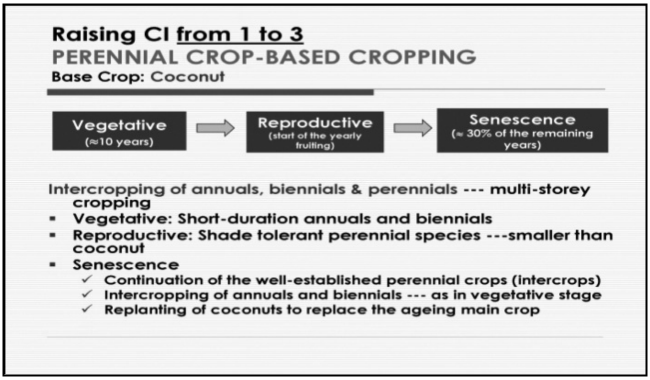


Figure 3. Raising crop index for perennial crop-based cropping from CI from 1 – 3 (Sta. Cruz, 2011)

Both research and experience show that a cropping index in all cases would require the following: synchronization of cropping schedules with the rainfall pattern, provision of supplemental irrigation, use of early maturing crop varieties/species, use of protective structures especially for high value crops, and provision of good pest and disease control. In the case of rice-based cropping, shortening of fallow period is also imperative. Only the coconut and perennial crop-based cropping requires the use of shade-loving crop species.

Villareal (1976) reported his practical observations on the interlinked factors which contributed to the success of multiple cropping synonymous to high CI in Taiwan: favorable climatic condition, excellent irrigation facilities, extensive application of organic and inorganic fertilizers, small farm size, and well-organized marketing systems. Except for favorable climatic conditions and small farm size, the importance of irrigation and use of fertilizers are already adequately covered in this paper.

Villareal (1976) considered the influence of favorable climatic conditions on both the farmers who practice multiple cropping and on the crops that follow after rice. With excellent irrigation, raising of the more intensively grown crops is only from October to March because at that time, temperatures are milder and very conducive to work. Farmers in thick sweaters working on their farms do not seem to get tired unlike in the tropical countries i.e. Philippines and Thailand where temperatures are much higher causing them to be less active. Most farmers crawl to weed their rice fields in winter planting than in summer planting. Temperatures in Taiwan from October to March are also more suitable for growing a variety of crops. Cool season vegetables such as cabbage, Chinese cabbage, onion and potato are specially favored in early winter through spring, Also, the warm days and cool nights are optimum for melon and tomato production. Still, more suitable varieties of crops for the climatic conditions of tropical Asia have to be discovered or developed.

The bottom line is beyond science, farmers should be industrious and willing to work hard and spend long hours in attending to their crops despite the harsh weather.

On small farm size, Villareal (1976) noted that, "Taiwan agriculture is that of gardening and not farming. Intensive and continuous cropping of farms, irrigation, and efficient protection against crop pests, characterize a typical market garden. Noteworthy are the very intensive operations such as: crawling to weed rice fields, training sweet potato vines, watering individual vegetable crop with liquid manure, cutting individual corn stalks above the ear, topping and pollination tomato, etc. One reason the massive intensive cropping systems in Taiwan are carried out successfully is their small farm. Average farm size in Taiwan was 0.84 in 1972 (Wang and Yu, 1973). Farmers are anxious to improve the productivity level of their farms and explore any possibility of obtaining extra income through the very intensive use of their limited land resources. Small farm size permits Taiwanese farmers to intensively crop their areas, which would have been difficult if their farms are bigger since farm family members are the main source of farm labor.

However, intensive monocropping and succession cropping of same crop year in and year out on the same piece of land will raise productivity but will ultimately result in soil fertility problems and build up of pests and diseases. Crop rotation and diversification to high value crops should be promoted to avoid these ecological problems and to enable farmers to take advantage of market opportunities and thereby achieve higher returns. The necessary agronomic technologies which are highly location- and market- specific can be systematically developed through the **All Philippine Farming Systems**

R&D Networks built around rice, corn and coconut, which together account for three-fourths of farm lands and small farmers. And this effort requires sustained financial support from both the government and the private sector.

Sta. Cruz (2011) summarized the issues and recommendations in raising cropping index:

Issue	Recommendation
Delineation of agricultural areas based on cropping system — an entry point for crop intensification	Development of land use plan at the municipal level delineating the areas (location and hectarage) for crop intensification based on dominant cropping systems
Crop intensification and municipal agricultural program	Integration of crop intensification program as a long-term component of the municipal agricultural program
Planning, development and implementation of the crop intensification program: • Setting of direction • Stakeholders • Extension	• Program goals and direction to be set at the national level— top down • Participatory planning, development and implementation by SCUs, LGUs and NGOs • Extension support program to address the technical and extension needs
• Irrigation water requirement • Capital/input requirement • Postharvest handling and marketing requirement	Support programs to address the key issues: • Water availability for crop production • Increased capital/input requirement • Increased production volume that may disrupt usual postharvest handling and marketing schemes

• Climate change on crop adaptation and pest shift • Pest management under intensified cropping • Energy problem and conventional agriculture • Sustainable agriculture • Introduction of 'new crops' in various cropping systems	Strategic RD support program to proactively address the key issues: • Impact of climate change on crops grown under multiple cropping scheme • Reduction of fossil-based inputs • Sustainable farming practices • Fitting of 'new crops' in the intensified farming scheme

Varietal Improvement and Agricultural Biotechnology

Crop agriculture starts with good seeds. The major improvement objectives include high yield, earlier maturity, adaptation to drought and water logging, tolerance to soil infertility, acidity and salinity; resistance to pests and diseases, and enhanced nutritive value and quality including storage and shipping traits. Much had been achieved and many more are yet to come with conventional breeding technologies by public and private plant breeding organizations. In addition, the new tools from modern biotechnology, e.g., DNA marker-assisted breeding and transgenics will greatly facilitate crop improvement and should be promoted.

The Philippines is the first Asian country to commercialize a genetically modified food crop. In 2002 during the first year of commercialization of Bt corn in the Philippines, 10,000 ha were planted to this product of modern biotechnology. Substantial yield increases of up to 37% were realized during the first year of planting, which translated to PhP10,000 additional profit for the farmer (Yorobe and Quicoy, 2006). A study of Bt corn ROI for cropping seasons from 2003–2004 to 2007–2008 showed consistently higher % ROI with performance ratio ranging from 1.1 to 1.9, in spite of the higher cost of Bt corn seeds (Gonzales, 2009). According to Gonzales, the use of Bt technology is more cost efficient, resulting in higher net income for farms which could lead to higher subsistence level carrying capacity. As of 2010, genetically modified corn (Bt corn, HT corn and stacked Bt and HT corn) was planted to 500,000 ha in the country (James, 2011), a 50-fold increase in 7 years.

With the impressive yield gains obtained using GM corn, the promise of modern biotechnology to contribute significantly to further improving agricultural productivity is underscored. Doubling the corn yield over the next twenty years from 10–20 tons per ha has been projected using combinations of biotechnology traits, marker-assisted breeding and advances in agronomic practices (Edgerton, 2009).

Although the target is to deliver twice as much food in 2050 as is produced today and deliver economic benefits to small and large farmers alike, these must be done with reduction of impacts to environment, while getting more food per unit land, water, and energy, and adapting to climate change by improving yield stability even under stress (Sachs, 2009).

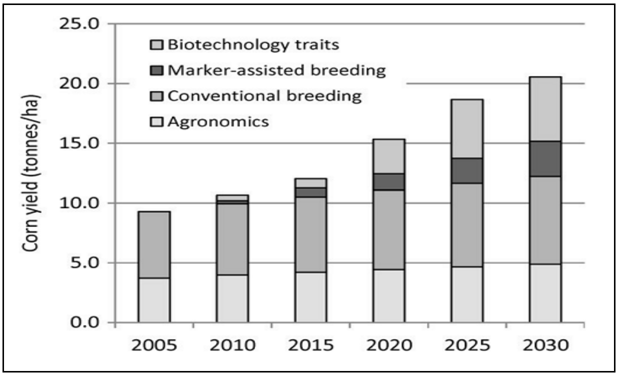


Figure 4. Projected impact of improvements in agronomics, breeding and biotechnology on corn yields in the United States. From Edgerton, 2009

The presently available biotech agricultural products corn, soybean, cotton and canola have desirable agronomic traits of insect protection and/or herbicide tolerance. In 2010, the GM crops were planted to 148 M ha in 29 countries (James, 2011). Herbicide tolerance trait accounted for 61% of the total global area planted to GM crops, followed by 22% for stacked traits of herbicide tolerance and insect protection, and 17% for insect protection. These GM products belong to the first wave or generation of biotech products which directly benefit the farmers. These traits will remain important but development of other important traits is being strengthened to help increase the yield of crops under various conditions. The different traits of biotech agricultural products which are at different stages of development include: (1) better pest resistance and weed control, (2) water usage efficiency, (3) nitrogen use efficiency, (4) intrinsic yield, and (5) quality traits.

Pest Resistance and Weed Control

From the present two stacked traits of corn borer resistance and herbicide tolerance, new corn varieties will exhibit multi-stacked traits which controls as many as 12 above and below ground insect pests that include corn borer, rootworm and multipest complex, and herbicide tolerance flexibility which can allow the use of either glyphosate or glufosinate applications (Syngenta, 2010). Corn varieties with third generation corn borer- and rootworm-resistance and tolerance to more than one herbicide are expected to provide more durable protection against a wider spectrum of insect pests and greater flexibility for use by farmers (Monsanto, 2011). Soybean which has herbicide tolerance to two types of herbicides and insect protection is now in the late stage of development. Monsanto is also developing soybean varieties with cyst nematode resistance using modern biotechnology and Asian rust resistance by advanced breeding using markers.

Bt eggplant has insect protection against fruit and shoot borer. It yields twice that of other varieties and will need 30% less pesticide. The Bt eggplant in India was approved for commercialization in October 2009 by the Genetic Engineering Approval Committee of the Indian government. However, its commercialization was put on hold in February 2010 due to safety concerns after protests from various groups against the technology. In the Philippines, the field testing of Bt eggplant continues although this was marred by uprooting of experimental plants at the University of the Philippines Mindanao in December 2010 and then at UP Los Baños in February 2011.

China's Ministry of Agriculture approved the commercial planting of Bt rice and GM phytase rice in November 2009 and it is expected that large scale cultivation of Bt rice will start in 2011. Huazhong Agricultural University developed the Bt rice while the Chinese Academy of Agricultural Sciences developed the phytase rice. India is conducting open field trials of Bt rice and commercialization is not expected in the next six years.

The development of sugarcane with insect resistance and herbicide tolerance is being conducted in India, Brazil, US, and South Africa.

Monsanto is using its Bt and Roundup Ready technologies in developing GM sugarcane which is at an early stage. South Africa is field testing GM sugarcane which include lines with the Bt gene. However, several groups have posed objection to further testing of GM sugarcane in South Africa due to biosafety concerns.

Water Usage Efficiency

Water is becoming a precious commodity and with increasing global food, feed and fuel demand, developing crops which are efficient in their use of water has become very important. The strategy in developing maize with superior water usage efficiency includes the use of the global maize germplasm, use of markers to aid in selection and genetic engineering tools to introduce drought tolerance traits. Syngenta released in 2010 its Agrisure Artesian™ technology of maize hybrids which are able to utilize moisture more efficiently on drought stressed areas. This technology was created through molecular breeding, mining genes from the corn genome which are responsible for efficient water utilization. Syngenta is also developing drought tolerant maize varieties using GM trait and these hybrids are expected to be available after 2015 (Syngenta, 2010).

Monsanto and BASF introduced a gene from *Bacillus subtilis* called *cspB*, which helps the bacteria cope with cold temperature, into corn which confers it drought tolerance and provides 7–16% yield advantage over control (Sachs, 2009; Gilbert, 2010). Pioneer-Dupont has a second generation combination of native and transgenic maize with improved 16% yield advantage in limited water conditions (Gilbert, 2010). In January 2011, Pioneer Dupont announced the release of its drought tolerant maize hybrid developed using marker-assisted breeding which followed the announcement of Syngenta on its own maize hybrid of similar trait in July 2010.

Performance Plants Inc. of Canada has developed the WET™ technology which allows plants to grow normally and produce excellent seed yields with significantly less water. Greenhouse experiments have shown that WET® plants produce 22% more growth with limited water. The effectiveness of the technology has been demonstrated in canola and is being developed for maize, soybean, cotton, ornamentals and turf grass (Performance Plants Inc., 2011).

Nitrogen Use Efficiency

Nitrogen fertilizer accounts for about 20% of corn production cost. Thus, increasing the efficiency of nitrogen use by corn (and other crops) will improve the crop's profitability. It is estimated that only 30–50% of applied nitrogen fertilizer is actually taken up by crops. This nitrogen use efficiency (NUE) trait will help plants to use nitrogen more efficiently by increasing yield under normal nitrogen conditions or stabilize yields under low nitrogen conditions. The big agricultural biotech companies (Monsanto, Syngenta and Pioneer) and small start-ups (Arcadia, Evogene, Performance Plants Inc.), as well as several research institutes and universities are developing nitrogen-use efficient plants but all initiatives are at proof-of-concept stage. Strategies to improve nitrogen use efficiency by genetic engineering include (a) increasing uptake efficiency by overexpressing transporters and (b) increasing physiological use efficiency by overexpression of key enzymes in nitrogen metabolism such as nitrate reductase, glutamine synthetase, and alanine amino transferase.

Monsanto started collaboration with Evogene in 2007 to use the genes discovered by the latter which help plants maintain yield even with lower applications of nitrogen. Yield gains of 23% for NUE transgenic corn plants at 0 level of nitrogen and 8% at 60 pounds applied nitrogen were observed for experiments in 2007–2008 for up to 16 locations. The main targets for the NUE improvement by genetic engineering are corn, wheat, rice and rapeseed. However, it is believed that improved agronomic practices could further increase nitrogen use efficiency. For the past 21 years, nitrogen-fertilizer efficiency of maize in the United States increased by 36% due to large investments in public sector research and extension education, investments by farmers in soil testing and proper timing of applying fertilizer (Tilman et al., 2002).

Intrinsic Yield

Two major approaches to increase the yield ceiling are improving photosynthetic efficiency and increasing biomass yield. Christou and Twyman (2004) discussed various strategies of genetic engineering which could potentially increase agricultural productivity.

Majority of plant species including rice utilize C3 type of photosynthesis which is much less efficient than C4. For example, for the same amount of fertilizer and water, maize, a C4 plant, will produce twice the biomass and yield twice of rice. The International C4 Rice Consortium led by the International Rice Research Institute and funded by the Bill and Melinda Gates Foundation aims to double rice yields through understanding the genes which are responsible for the different photosynthesis mechanisms in plants and ultimately finding ways to convert the photosynthetic mechanism in rice from C3 to C4 for more efficient photosynthesis (http://irri.org/c4rice). The consortium estimates 15–20 years of collaborative work to attain its goal of developing C4 rice.

Increasing biomass yield is a primary goal of companies and researchers working on biofuels. This involves understanding the molecular mechanism of biomass improvement. Some of the studies being undertaken towards this are: (a) analyzing gene expression involved in biomass accumulation; (b) identifying key microRNAs important for biomass accumulation and stress tolerance; and (c) constructing and DNA marker genetic map and identifying key QTLs for biomass accumulation (http://www.okepscor.org/research/cellulosic-bioenergy-research). Performance Plants Inc. is introducing its Biomass Enhancement Technology™ into crops and results in the screenhouse showed significant biomass increases. Model plants with this technology produce twice the biomass by enhancing vegetative plant growth (http://www.performanceplants.com/).

Quality Traits

Among the quality traits that have been targeted for improvement using modern biotechnology tools are:

(a) Enhanced nutritional quality, e.g., higher vitamin and Fe content. In Golden Rice, two genes were introduced to produce the β-carotene, the precursor of Vitamin A, in the grain endosperm. The second generation Golden Rice has 31 μg of β-carotene, 23 times greater than the original Golden rice (Golden Rice Project, 2011). Various national rice research institutes in different countries including the Philippines have introgressed the Golden Rice into their elite lines and are in the process of field testing it. PhilRice plans to conduct a confined field test which will be followed by multilocation field trials for several seasons. PhilRice is also developing Golden Rice with two other important traits, tungro and bacterial blight resistance.

(b) Improved nutritional profile, e.g., improved amino acid or fatty acid profile. Monsanto is developing high oleic and omega-3 soybeans. Vistive® Gold has mono-unsaturated oil like olive oil and low saturated fat like canola. SDA omega-3 soybean will produce oil with the omega-3 fatty acids which have heart health benefits. Both technologies are nearing completion and release.

(c) Improved processing qualities. Syngenta recently obtained full deregulation for its Enogen™ corn which has α-amylase trait. This trait will allow dry grind ethanol production which can generate higher ethanol yield (Syngenta, 2011).

(d) Improved postharvest qualities. Postharvest losses account for up to 30-40% of production. We have developed papaya with long shelf life or delayed ripening trait. For control nontransgenic papaya, it takes 5–7 days from color break to ripe stage, compared with 11–14 days for long shelf-life papaya (Tecson-Mendoza et al, 2011). Plans for the field testing of this technology under biosafety regime are now being made.

Water Use Efficiency

Water has long been recognized as one of the most critical inputs to agricultural production systems. For rice production alone, irrigation water management constitutes close to 30% of the yield gap (Ferguson, 1987). Furthermore, crop yield and cropping intensity are both increased with irrigation. For rice cropping systems alone, recorded data in the Philippines show that crop yield is generally higher under irrigated than under rainfed conditions. At the same time cropping intensity is increased with irrigation particularly under Type I climatic conditions. Instead of one cropping under rainfed agriculture, the number of cropping can be doubled or even tripled with irrigation. Consequently, the land area available for agriculture is virtually doubled or tripled. Currently, irrigation development in the Philippines is less than 50%, with potential irrigable area estimated at 3,126,340 has and actual irrigated area as of 2009 was reported to be 1,539,377 has (BAS, 2011). With irrigation, this land area available for cropping can be doubled or tripled. All these point toward the fact that water plays a major role in agriculture especially when intensification that would enhance agricultural productivity, sustainability and competitiveness is targeted.

However, water resources dependability in the Philippines, both surface and groundwater, has become an issue not only because of the potential consequences of climate change but of the seemingly inadequate measures to protect watersheds and aquifer systems in the country. As a result, the issue of water use efficiency has come into play. And this has become even more critical for the agriculture sector as it consumes about 88% of the total water resources in the country (FAO, 2011).

The term water use efficiency is a loosely defined term. From a purely hydraulic or technical standpoint, water use efficiency refers to the ratio of the amount of water beneficially used to the amount of water delivered or withdrawn. From other points of view, it may refer to the mass or value of agricultural produce per unit amount of water withdrawn. For practical purposes, water use efficiency will be defined in this paper as simply the degree by which the use of water withdrawn from a given source for whatever purpose is maximized. This implies minimization of unnecessary losses and wastage during conveyance and during water application. Applied to crop production systems, this means maximizing the amount of water withdrawn from any source for irrigation purposes and eliminating irrigation conveyance and application losses.

Therefore, it is imperative that agriculture must do with less water. Fortunately, we have a number of technologies and practices which have been developed over the years to address water scarcity and adequacy problems. Although they require further research to generate new knowledge and information to maximize the benefits under local conditions they can address the issue of water efficiency.

Drip irrigation

Drip or trickle irrigation involves the use of flexible pipe and emitters to deliver just the right amount of water to crops to be irrigated at relatively low pressure. This technology can be used to irrigate almost any crop and can be adapted to any soil, climatic and topographic conditions. It offers special agronomical, agrotechnical, and economical advantages for efficient use of water and labor (Keller, 2002). Drip irrigation can also be used under limited water supply conditions. In the recent years, low-cost drip irrigation technologies have evolved and have been tested and applied in the Philippines (e.g. Ella et al., 2010 and 2009). But regardless of the cost, drip irrigation maximizes water use efficiency since the amount of water delivered is just sufficient to supply the evapotranspiration requirement of the crops to be irrigated. Hence, runoff and percolation losses are avoided and irrigation efficiency is maximized. Drip irrigation has also been proven to increase crop yield (Ella et al., 2009).

Alternate Wetting and Drying

Alternate wetting and drying technology involves the application irrigation water (wetting) several days after the infiltration of ponded water or when the saturated zone has lowered to a specified level in the rootzone (drying). This is particularly applicable for irrigating lowland rice. This technology has been widely applied in other countries like China. It is being promoted in the Philippines by the International Rice Research Institute (IRRI) (Bouman and Lampayan, 2009). This technology is subject to further refinement to continued research (e.g. Samoy, 2010).

Alternate wetting and drying technology obviously increases water use efficiency in that irrigation water is used intermittently and evaporation losses are minimized.

Conservation Agriculture—a Biological Engineering Approach

Conservation agriculture is a biological engineering approach to farming based on the principles of minimum soil disturbance, continuous mulch cover and diversified crop rotation. Indirectly, this technology improves soil quality including soil moisture retention due to increased organic matter. This technology has been widely adopted in many parts of the world. In the Philippines, this technology in its truest sense of the word, is relatively new and is the subject of ongoing research (Reyes, 2010; Ella, 2010).

This biological engineering approach to agriculture can increase water use efficiency indirectly through increased soil moisture retention.

Consequently, percolation and runoff losses during water application from either irrigation or rainfall are minimized.

Proper irrigation water management at the farm and system level

Proper irrigation management at the farm level involves proper application rate, irrigation period and irrigation interval. Whether irrigation is accomplished by surface methods (basin, border, furrow, corrugation, wild flooding), overhead (sprinkler, drip or trickle) or subsurface methods, the minimization of application losses depends on the application rate, duration of application and irrigation interval. The calculation of these irrigation parameters requires basic knowledge of soil-plant-water relations and soil water dynamics. For surface irrigation methods alone, the variability of the net opportunity time for infiltration along the strip to be irrigated could be greatly minimized with proper choice of irrigation application rates and duration. At the same time, percolation and surface runoff losses could be greatly minimized with proper irrigation water management.

At the system level, proper irrigation water management involves proper amount and timing of water releases to avoid conveyance losses. Again by minimizing water losses, irrigation efficiency is maximized.

Irrigation by demand or by rotation

One of the major reasons why irrigation water use efficiency is relatively low in rice-based cropping systems in the Philippines is the fact that irrigation is allowed to flow continuously in irrigation canals even if irrigation application has already been accomplished. This obviously results to so much water wastage as unused water discharge is continuously lost to the drainage canals. An alternative approach that would dramatically increase water use efficiency is through irrigation by demand, i.e. delivering irrigation water to the farm or group of farms only when it is needed. After irrigation has been accomplished the flow of water into the irrigation canals is shut down using appropriate water control structures.

The other alternative is irrigation by rotation. In this approach, water is delivered to a farm or group of farms by rotation. That is, for any given period, only a farm or group of farms is served by the irrigation system. Irrigation service is then moved to the next set of farms and so on until the entire service area has been irrigated. In this way, conveyance and application losses are minimized and hence water use efficiency is maximized. With optimal water allocation and distribution, the water use efficiency using irrigation by demand or by rotation can be further increased.

Improvement of conveyance and water delivery system

During conveyance of water from the source to where it will be used beneficially, water losses are incurred due to seepage and percolation and other conveyance losses. The maximization of conveyance efficiency is therefore dependent on the minimization of these conveyance losses. Conversely, the water use efficiency at the system level could be increased through the improvement of the conveyance system. For irrigation canals, the provision of lining material for the channel bed could greatly minimize seepage and percolation losses. Illegal diversion and other conveyance losses could also be prevented with a properly designed and maintained canal network.

Development of minor irrigation systems

Minor irrigation systems refer to farmer-controlled and small-scale irrigation systems (David, 2003). This includes shallow tubewells, deep tubewells, low-lift pumps, small farm reservoirs among others. Minor irrigation systems obviously eliminate excessive conveyance losses as water withdrawn is within or close to the farms to be irrigated. Moreover, being farmer-controlled irrigation application losses can be greatly minimized. Consequently, the water use efficiency can be greatly increased with minor irrigation systems.

Optimal water resources allocation

In view of competing water uses for various purposes such as agriculture, domestic, industrial, power generation, aquaculture, recreation, etc., available water resources in the country should be allocated in an optimal fashion. This may require the use of optimization models with maximum benefits as the target objective function and dependability as one of the constraints. In this way, water losses due to arbitrary allocation of water resources can be minimized and hence the water use efficiency can be maximized.

Water recycling and reuse

When excess irrigation water, which would otherwise go down the drain, is reused or recycled to irrigate the same farm or nearby farms, then losses are minimized and hence water use efficiency is increased. This old concept of water recycling or reuse can even be extended to wastewater, which when properly treated could be used for irrigation purposes.

Water conservation and sustainable water resources management

Water conservation can be done at the system level or at the farm of field level. This involves not only the traditional concept of saving water during the rain season for use during the dry season but also the minimization of water losses due to seepage and evaporation. Again, by reducing the water losses the water use efficiency can be greatly increased.

All technologies and practices would, however, be useless if there is no sustainable water resources management to start with. This involves proper protection of watersheds and aquifer systems. After all, without sustainable supply of water there is no water use efficiency to talk about. Equally important is the issue on prioritization and management of irrigation projects. For instance, the current area under irrigation is 1.5 million hectares out of the potentially easily irrigable area of 3.1 million hectares. The bulk of the existing irrigation areas are under the National Irrigation System (NIS) and Communal Irrigation System (CIS). However, the reported cropping intensities for NIS and CIS are 1.49 and 1.11 respectively indicating that they are grossly underperforming. Thus, priority should be given to the rehabilitation and better management and maintenance of existing irrigation over the construction of new systems which require billions and a long term development (PA 2020).

Dr. Emil Q. Javier (2011) made the following statement on this issue during the NAST annual scientific meeting.

> "…the NIA indicative plan calling for P20 billion annually for irrigation is unlikely to be met. An annual allocation of P10 billion p.a. is more realizable, thus leaving P6 billion p.a. after deducting the mandatory payments for San Roque and Casecnan. These amounts will be supplemented by the water users fees from current

> irrigation systems if collected properly in the order of P2-3 billion p. a. These amounts should be judiciously divided between restoration and rehabilitation of NIS and CIS systems and complimentary investments in small irrigation systems i.e. farm and village level ponds and reservoirs, shallow tube wells and low lift pumps. Likewise, improvement in management of irrigation projects through staff training and development and application of new operating procedures are needed to ensure greater water use efficiency, equity of water distribution across areas and timeliness of water delivery. "

Moreover, the participants of the Annual Scientific Meeting (NAST PHL, 2011) presented the following resolution to the Department of Agriculture (DA) to address the above mentioned concern,

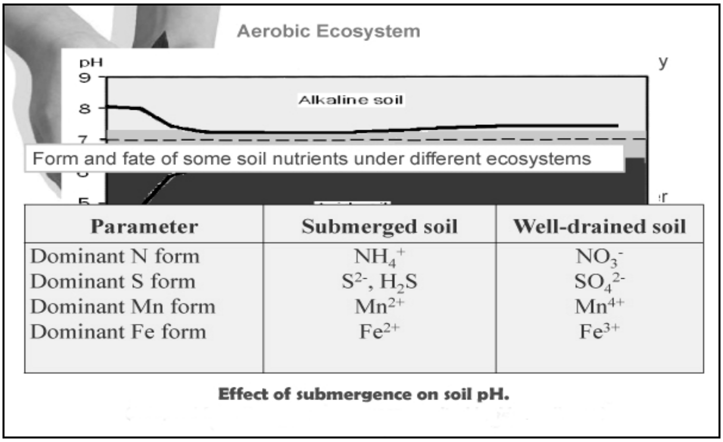
> "Comprehensive external review of the National Irrigation Authority (NIA), its mandate, functions, performance, future plans and programs; Exploring the possibility of allowing Irrigators Associations to keep the majority of irrigation fees, of providing incentives for them to organize their associations, pay and collect water fees and properly maintain and manage irrigation systems…"

Integrated Nutrient Management (INM)

The unabated population growth demands constant increase of food supply and to meet this demand require increase in yields or expansion of production area, use of high yielding crops and increase in inputs use. These could cause pressure on the soil resources and the quality of the environment as evident from the survey conducted nationwide on the nutrient status of rice soils, thus the importance of INM. It is defined as the judicious application of inorganic and organic fertilizers in proper proportion, rate, time and method of application based on the nutrient requirement of crops, nutrient levels in soils plus sound cultural management practices in crop production.

INM has a number of benefits: maintains and/or enhances soil fertility and plant nutrition at an optimum level to sustain desired crop productivity; utilizes both inorganic and organic fertilizers resulting in the increase of nutrient use efficiency from other sources; and is an effective strategy in attaining sustainable agriculture (Mamaril, 2011).

For efficient application of INM, it is imperative to consider the ecosystems where crops will be grown: aerobic vs anaerobic since the form and rate of nutrients will vary under different ecosystems (**Figure 5**), and yield potentials, maturity and resistance/susceptibility to physiologic stresses of crop species/varieties. For instance, under anaerobic condition the dominant N form is NH_4^+ while it is NO_3^- under aerobic condition (Ponamperuma, 1985, as cited by Mamaril, 2011).



Parameter	Submerged soil	Well-drained soil
Dominant N form	NH_4^+	NO_3^-
Dominant S form	S^{2-}, H_2S	SO_4^{2-}
Dominant Mn form	Mn^{2+}	Mn^{4+}
Dominant Fe form	Fe^{2+}	Fe^{3+}

Figure 5. Aerobic Ecosystem (Ponamperuma 1985, as cited by Mamaril, 2011)

High crop yields and higher cropping intensities will ultimately exhaust the ability of the soil to supply the nutrient requirements of crops grown on them. Exogenous nutrients must be applied judiciously as chemical fertilizer and as organic manures to replace those taken up by plants and those lost to the environment.

Soils supply essential mineral nutrients, harbor microorganisms beneficial to root and plant growth and provide anchorage to plants and conduit for water. Nitrogen, one of the three major nutrients is plentiful in the atmosphere. A substantial part of the nitrogen requirements of crops can be sourced from the air through the free-living nitrogen-fixing soil microorganisms and those which symbiotically reside in the root hairs of some legume plants. Leguminous crops should be included in crop rotations to fix nitrogen from the air and build up organic matter content of the soil. Phosphorus and other minerals are often locked in unavailable forms among the soil clay particles. Similarly, soil microorganisms can be deployed to accelerate mineralization into compounds available for plant use. The National Molecular Biology and Biotechnology Institute at UP Los Baños has isolated and popularized soil microorganisms which fix nitrogen from the atmosphere, mineralize nutrients, promote root growth and control soil-borne pathogens. A good example is Bio-N, a microbial-based fertilizer mainly composed of microorganisms (bacteria) isolated from the roots of *talahib* (*Saccharum spontaneum*). These bacteria can convert atmospheric nitrogen (N_2) into a form usable by rice, corn and vegetables and can enhance short growth and root development (Biotech UPLB, 2008). The search for more efficient cocktails of soil microorganisms as biofertilizers and bioinoculants should continue. Moreover, additional efforts are needed to facilitate their commercialization.

Farm residues contain a lot of mineral nutrients. They should not be burned but recycled as organic manure. Commercial microorganism preparations must be developed to hasten their degradation. Organic materials are generally low and variable in nutrient contents but may contain not only macro but also micronutrients. They vary in carbon:nitrogen ratio, thus rate of mineralization also varies. Commercial organic fertilizers may contain heavy metals and pathogens which may end up in food chains. While green manuring may contribute in sustaining soil fertility, small farmers are hesitant to adopt due to low financial return. Based on nationwide experiments on lowland and rainfed rice, certain biofertilizers were found not effective. Foliar fertilizers are not consistently effective. Inoculants do not show consistent effect. However, the emphasis should be on producing organic manure on farm rather than on commercial production of organic manure sold in bags like chemical fertilizers to offset the high cost of transport.

Chemical fertilizers are costly but very often the gain in yield offset the additional cost of fertilizer. The use of commercial chemical fertilizers should be made more efficient and effective with slow, controlled release formulations, precise timing and placement. The necessary agronomic measures to minimize soil erosion such as zero tillage, cover crops, mulching, terracing, hedgerows and grass strips for slope lands, should be popularized.

In conclusion, INM will contribute significantly in sustaining soil productivity provided that the appropriate technologies are adopted for the proper conditions. No one technology is appropriate for all conditions (Mamaril, et al, 2009; Cosico, 2010; Mamaril, 2011). The complementary benefits of organic and inorganic fertilizers are good examples. While inorganic fertilizers provide adequate nutrients, the organics can improve and condition the physical, chemical and microbiological properties of the soil.

Integrated Pest Management (IPM)

Pest and diseases are permanent features in crop agriculture. The struggle to control pests and diseases is a never-ending challenge as these biological entities continually evolve relative to their hosts and preys. A good example is in the case of the 1999 breakdown of resistance to wheat stem rust. In the 1950s, the late Norman E. Borlaug, Nobel Peace Prize winner and renowned plant breeder, led a team of scientists to develop high yielding wheat varieties which were resistant to wheat stem rust. This stem rust had ruined 40 per cent of spring wheat crop in Northern America. These high yielding and rust resistant wheat varieties helped launch the Green Revolution and protected wheat for more than 50 years. However, in 1999, a new virulent strain of wheat rust called Ug99 was discovered in Uganda. Worldwide, wheat varieties rely on only a few resistance genes and majority of these genes do not give adequate protection against Ug99 (Singh et. al., 2008). In addition to being pollutive and costly, control measures with pesticides are often ephemeral measures as the pest organisms develop resistance and/or other pests succeed them (Bernardo, 2011).

Integrated pests management (IPM), the judicious combination of biological, cultural and mechanical methods, and in the dearth of such measures, chemical control agents, is proving to be a safer, cleaner, more cost effective and sustainable manner of crop protection. This trend is being reinforced by the increasingly stringent pesticide residue standards imposed by food importing countries and local environment and health authorities.

IPM is a continuing delicate balancing act, quite location specific and relatively knowledge intensive. In general, much research has yet to be done before IPM can be an integral part of agricultural production practices in the country. These include a better understanding of the ecological balance among host pests and diseases, breeding for stable, horizontal pest and disease resistance, and use of more benign biodegradable pesticides as well as deployment of predators and natural enemies. In other words, wide acceptance can be achieved with better science and informed policies as demonstrated by the diminishing use of pesticides in rice fields in much of Asia (Bernardo, 2011). Institutionally, this would require strengthening of R&D units like the National Crop Protection Center at UPLB, the Bureau of Plant Industry network of regional crop protection centers and the DA-RIARCs. Also required are disciplinary research groups in the state universities and colleges (SUCs) studying basic systematics, morphology, physiology, reproductive biology and ecology of pests and disease organisms, predators and hosts.

It is equally important to train more experts who will actively pursue the science of IPM and extension specialists who will deliver the technology to farmers. All of these require solid financial support from both the public and private sector.

Labor Productivity and Mechanization

Unit labor costs in the Philippines are higher than those in our ASEAN competitors, Thailand, Indonesia and Vietnam, except Malaysia. But Philippine value added per agricultural worker of US$103 has a long way to go to match Malaysia's labor productivity at US$877 per agricultural worker (**Table 1**).

Table 1. Labor productivity in agriculture in the region

Analytical Grouping/Country	**Arable land (hectare/capita)**		**Agricultural value added/unit of labour ($)**	
	1979-81	1994-96	1979-81	1995-97
Malaysia	0.07	0.09	3,279	6,267
Philippines	0.09	0.07	1,347	1,379
Thailand	0.35	0.29	630	928
Indonesia	0.12	0.09	610	745
Lao, PDR	0.21	0.17	---	526
Cambodia	0.30	0.37	---	407
Vietnam	0.11	0.07	---	---
Bangladesh	0.10	0.07	181	221

(Adapted from ILO, 2001)

The level of agricultural mechanization must be raised to raise labor productivity and justify high wages. A suggested practical solution is to mechanize most farm operations as successfully done in Taiwan, Korea and Japan. For example, in the case of rice farming, mechanization has been practiced from land preparation, seedling production, transplanting, spraying, harvesting, and drying. The extent of mechanization in Taiwan is 98% (Din-Sue Fon, 2005). In the Philippines, 80% of farm power is provided by human beings (Paras and Amongo, 2005).

Table 2. Mechanization System vs. Productivity

	Mechanization System	**Productivity**
1	Manual farming	1,000
2	Irrig 1, light animal cultivation	2.000
3	Irrig 1, heavy animal cultivation	3,500
4	Irrig 2, heavy animal cultivation	5,000
5	Irrig 2, mechanized cultivation, animal traction	10,000
6	Irrig 2, motorized mechanization	30,000

Source: FAO, 2000

Table 2 shows productivity under various mechanization systems compared to manual farming (FAO, 2000). Benefits from mechanization are clear cut. Experts however, claim that although mechanization has distinct superior efficiency and enhanced labor productivity, there are barriers that impede the growth, sustainability and adoption of farm mechanization. Such impediments include: technological constraints, socio-cultural and behavioral barriers, financial and economic problems, and environmental issues.

In the international workshop on small-farm mechanization (FFTC, 2005), it was concluded that the extent and choice of agricultural mechanization directly affects land and labor productivity, farm income, environment, and the quality of life of small-scale farmers. Hence, the requirements for basic farm mechanization to cater to small-farm needs must be met. These requirements include: suitability to small farms; simple design and technology; versatility for use in different farm operations; affordability in terms of cost to farmers; and most importantly, the provision of support services from the government and the private sectors/manufacturers.

Political will is cited as a common factor for successful farm mechanization programs in highly mechanized countries. Therefore, efforts on small-farm mechanization must be based on a holistic and integrated strategy that considers the actual needs and priorities of the small-scale farmers.

The need to consolidate small farms to efficiently mechanize small farms was also emphasized. Such innovation allows for the entry and travel of tractors and other implements, provision of efficient irrigation and drainage, road access systems, and establishment of on-farm post harvest facilities and other infrastructures. Land consolidation as practiced by BMD Cornworld in Isabela includes custom hiring services and clustering of services and shows that it is workable and feasible (Lantin, et al, 2003). According to Mr. B.M. Domingo, he resorted to this scheme for three major reasons: lack of hired laborers during the peak labor seasons; farmers save time; do not have to wait for hired laborers; and avoid postharvest losses and with pre-arranged custom provider, farmers could have time for other jobs.

Summary and Conclusion

This paper analyzed some key factors and issues to further intensify agriculture for productivity, sustainability and competitiveness, specifically: land use and administration, raising cropping index, varietal improvement and agricultural biotechnology, water use efficiency, integrated nutrient management, integrated pest management and labor productivity and mechanization.

To integrate, unify and synchronize the system of land use planning at all levels in the country, the enactment of enabling laws such as Comprehensive National Land Use Plan Law, Lands Administration Reform Law, and the Lands Administration Authority was proposed. The completion of cadastral maps to define forestlands, protected areas and ancestral domains was also deemed essential. LGUs also have to complete their respective comprehensive land use plan to serve as an integrating framework in the management of resources. Finally, more experts in land planning, accounting and allocation of land resources in the university, in government, in the LGUs and stakeholders, are needed for better planning and implementation of the land use projects.

To further improve land productivity, the cropping index (CI), i.e., crop yields per cropping, has to be raised. Increasing the CI in the country's agricultural lands has to be done on area-basis, i.e., on properly delineated areas that will allow accounting of various interventions directed towards increasing crop productivity. Raising the CI would require the following: synchronization of cropping schedules with the rainfall pattern, provision of supplemental irrigation, use of early maturing crop varieties/species, use of protective structures and provision of good pest and disease control.

Crop agricultural productivity depends to a large extent on the use of good varieties. While conventional breeding and advanced agronomic practices can bring about 30% higher yield, doubling of yield can be brought about by the combination of present biotech traits of yield protection and new traits being developed such as drought tolerance, nutrient use, drought and flood tolerance, and other yield-enhancing traits. Various biotech crops with said traits are now at different stages of development. Further, biotech crops with enhanced nutritional value and quality are being developed. In the Philippines, corn with insect pest resistance and herbicide tolerance is planted to half million hectares. On the other hand, Bt eggplant with insect pest resistance is now being tested in several locations in the country while Golden Rice with pro-Vitamin A and papaya with long shelf life are awaiting field testing.

Water plays a major role in agriculture especially when intensification to enhance agricultural productivity, sustainability and competitiveness is targeted. Applied to crop production systems, water use efficiency means maximizing the amount of water withdrawn from any source for irrigation purposes and eliminating irrigation conveyance and application losses. Further, technologies and practices in agriculture should make use of less water to address water scarcity and adequacy problems. Some of these technologies and practices are drip irrigation, alternate wetting and drying technology, conservation agriculture, proper irrigation water management at the farm and system level, irrigation by demand or rotation, improvement of conveyance and water delivery systems, minor irrigation systems, and water recycling and reuse.

Integrated nutrient management is the judicious application of inorganic and organic fertilizers in proper proportion, rate, time and method of application based on the nutrient requirement of crops, nutrient levels in soils plus sound cultural management practices in crop production. For efficient use of INM, the ecosystems where crops are grown have to be considered since the form and rate of nutrients use will vary under different ecosystems. Nutrients such chemical fertilizer and organic manures must be applied on soil to replace those taken up by plants and those lost to the environment. Other requirements of plants can be sourced from soil microorganisms, leguminous plants and other sources. The complementary use of inorganic fertilizers which provide adequate nutrients and organics which can improve and condition the physical, chemical and microbiological properties of the soil can significantly contribute to sustaining soil productivity.

Integrated pests management (IPM) is the judicious combination of biological, cultural, mechanical methods, and chemical control agents and provides a safer, cleaner, more cost effective and sustainable manner of crop protection. However, the need for a better understanding of the ecological balance among host pests and diseases, breeding for stable, horizontal pest and disease resistance, and use of more benign biodegradable pesticides as well as deployment of predators and natural enemies was emphasized before IPM can really become more widely adopted in the country. The need for more highly trained IPM experts and extension specialists to transfer the technology to farmers was underscored.

To raise the country’s low level of agricultural labor productivity, it is recommended that the level of farm mechanization be raised. Farm mechanization in the Philippines is estimated at 20% compared with 98% in Taiwan. Barriers that impede the growth, sustainability and adoption of farm mechanization are technological constraints, socio-cultural and behavioral barriers, financial and economic problems, and environmental issues. Consolidation of small farms as in the case of Cornworld in Isabela to efficiently mechanize them was emphasized. Such innovation allows for the entry and travel of tractors and other implements, provision of efficient irrigation and drainage, road access systems, and establishment of on-farm post harvest facilities and other infrastructures.

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