Technology for Overcoming the Global Tetralemma

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***Abstract*—We humans are now facing the four global issues (Global Tetralemma) related to Population, Food, Energy and Environment. The key issue is how to find out the cause of these problems and what are the possible solutions. Simply put, most of the problems are caused by human activities prioritizing economic promotion. It can be, however, noted that agriculture has a higher potentiality to play an important role in solving most of the problems in question. In this paper, the technologies being applied or to be applied to agriculture and its related sector are introduced focusing on the sustainable development of future society building, which means establishing and maintaining a harmonic balance between ecology and economy.**

Keywords - global tetralemma; space era high-tech agriculture; agricultural mechanization; policy and technology.

I. Introduction

Earth is the only planet on which humans can live a normal life. The global tetralemma refers to the four global issues consisting of population, food, energy and environment. Figure 1 shows this ecological concept. When the population increases, the food production must be increased. To increase the food production, more energy is needed. Energy consumption increases CO_2 production, which jeopardizes the environment. This creates a situation in which we, humans are facing three problems related to food, energy and the environment.

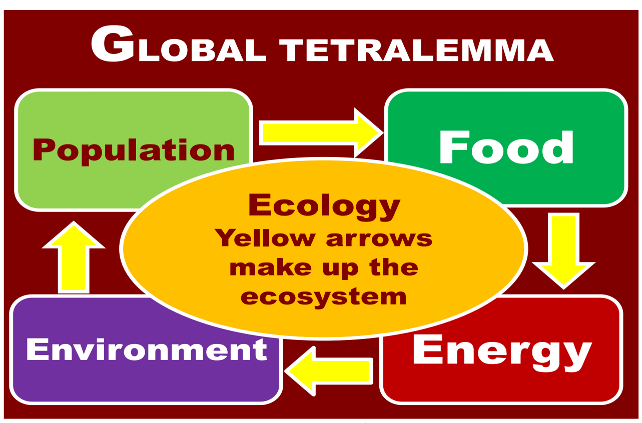

Figure 1. Schematic concept of global tetralemma

Figure 2 shows how economy breaks ecology and produces all the other problems. How to tackle and find the solutions for those problems is one of the main objectives of this paper.

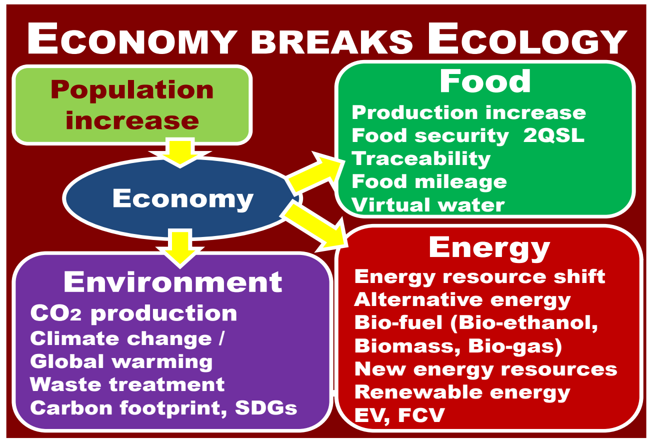

Figure 2. Economy breaks ecology and contributes to other problems

Currently, the world population is 7.8 billion and increasing by 80 million per year. Considering this figure carefully, about 140 million people are born and 60 million are dying each year. The difference of 80 million is the population increase. As the population grows, more food production is needed. It is said that the population engaged with food production is around 20% of the world population. This simply means that one farmer produces food for 5 persons, including himself.

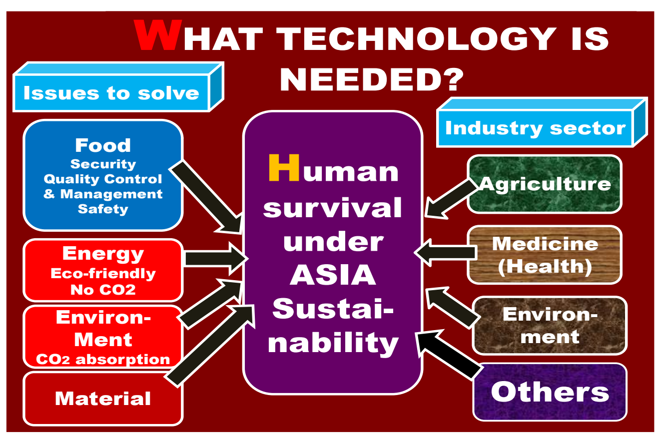

Figure 3. What technology is needed for.

Figure 3 shows the relationship between the issues we are facing and the industry sector. We are already facing two emerging global issues related to energy and the environment that we need to solve immediately, however, the final and optimum solution has not been found yet, in spite of many efforts being done by various scientists, researchers and engineers. This is really a competition of the production cost and price of petroleum with the other energy resources in which most of them are eco-friendly or environment friendly ones. Recently, petroleum price has been drastically coming down almost 1/3 compared to ten years ago, due to the new energy resource discovery of shale gas, in which the production cost is very much lower and more competitive. Methane hydrate is another possibility. Japan successfully developed the technology to take it out of the seabed in 2014, however, it is still not cost competitive. It will take a little bit more time to make it for the commercial base production. It may be guessed that the decrease in price of the petroleum may slow down the speed of technology development due to enough production to supply the market. On the other hand, the mitigation control of CO_2 gas may be delayed, and the global warming issue cannot be improved if this situation is continued. Which one should be chosen, energy or the environment, is one of the good examples to think about the real meaning of sustainable development or low carbon society building from the viewpoint of how the harmonic balance can be well maintained under this condition in promoting economy without jeopardizing the environment. The economy always makes us hesitate easily in making a choice. We, humans, already know that the fossil energy should not be chosen due to the cause of the global warming, however, the lower prices of oil entice us.

The author delivered a lecture entitled “Asian Agriculture Growth Strategy” in Prime Minister ABE's doctrine "ABEnomics” as one of the invited keynote speakers at the Agricultural Mechanization Session, JSAMFE (Japanese Society of Agricultural Machinery & Food Engineers) annual meeting held at Ryukyu University, Okinawa, Japan, May 17, 2014 [1][2]. Figure 4 is a schematic diagram showing ASEAN Economic Community should pick up the industrial sector for promoting the economy and how it should be done. It is already known that the ASEAN Economic Community was officially established in December 2015, however, it looks a little bit difficult to know what sector should be set as the main framework of the body to meet and achieve the final goal of the community. In the author's understanding, the goals should be 1) To make ASIA the world food pantry, enough to supply safe food on demand and 2) To stabilize the economy and maintain peace based on agriculture. The following shows the concept outline of ASEAN Economic Community proposed by the author and how it should be promoted step by step towards the final goal achievement.

Most Asian countries are more or less still relying on the economy of the agricultural production. ASEAN member countries are also in similar situation, except some of them. It is already well known that, as already mentioned above, the human population is still rapidly increasing at the rate of 80 million per year. It can obviously be guessed that, sooner or

Figure 4. Asian Agriculture Growth Strategy

Later, the food issue will become a serious problem. Fortunately, Asia is producing a huge number of bio-resources, especially food resources, however the quality is not well controlled and managed. As far as food production is concerned, the priority should be to secure the safety. It should be noted that there are two kinds of countries in Asia: one kind is resource-oriented countries, and the other kind is technology-oriented countries, called ASEAN, plus three like China, Japan and South Korea. To secure the quality, especially food safety, higher technology is needed and applied. The author's proposal is based on the collaboration and mutual competition among these two types of countries. One needs the resources and the other needs the technology. Both need them mutually and interactively. The best way is to collaborate and compete to promote a stable economy in Asia. In addition, two things should be done on the process of final goal achievement. They are: 1) Technology transfer and 2) Human Resources Development. Both should be desirably promoted in parallel, however, due to some inconvenience of laws and regulations, it is hard to achieve in practice. Which one should be started first? That is the human resources development, especially for universities. The extension must be followed through the process of technology development and its validation; therefore, it takes time for final technology transfer to extension. Even for the human resources development, it takes time until the effective result could be found, therefore, the academic mobility program should be started earlier and promoted in the regional area. It is required that highly educated human resources will be absolutely needed by the mature global society. Two stages of goal achievement are shown towards the final one. The first step is to make Asia one of the world food pantry in huge amount of food resources production. Secondly, the most reliable Asian brands of foods should be created enough to guarantee both quality and safety. Following the process based on this proposed concept, the Asian economy can be developed and promoted stably, and regional peace can also be kept. Both resource-oriented and technology-oriented countries can get mutual prosperity to survive together contributing a lot in safe food production and supply all over the world (Figure 4).

II. SMART AGRICULTURE

The Ministry of Agriculture, Forestry and Fisheries of The Government of Japan defines smart agriculture as "new agriculture that enables hyper labor saving and high-quality products production by utilizing cutting-edge technologies such as robotic technology and ICT". According to the Ministry, the materialization of smart agriculture can achieve hyper labor saving and large-scale farming production by automatic control of agricultural machinery, high-yield, high-quality products production that makes full use of sensing technology and large data, and heavy labor by using robot technology. It can be expected to have more merits such as CO_2 mitigation and labor saving, simplification of agricultural operation by combining know-how with data and assisting operating function and providing important and necessary information to consumers by providing final products information (traceability) [6].

A. Precision Agriculture

Precision Agriculture has variable rate control function for reducing loss and saving materials and energy. The concept of this farming system is similar to the TOYOTA car manufacturing system named “Kanban (or Kaizen)" system mainly consisting of the three conditions listed below. In the car manufacturing industry, the parts must be prepared in advance and supplied timely based on the production plan and schedule.

1) The required parts must be prepared in advance based on the production schedule
2) Provide just enough amount required
3) Provide them timely when required

In actual farming, three conditions of “What”, “How many or How much” and “When” must be decided from time to time knowing the data provided by GIS is specifically matched with site by site.

B. Robotics

There are two kinds of robots. One is something like an industrial robot set and used to complete the work for the post-harvest products, such as selection, weighing, grading, sorting, packaging etc. in a specially prepared building or facility. The other is a mobile vehicle type, such as tractor, combine and transplanter doing the original operation while moving things, such as tillage, fertilizer application etc. The location of the robotic machine is autonomously guided by the GPS signal provided from the satellite. The optimal operation can be done under the variable rate control based on the final decision derived from the data collected and provided by GIS continuously from time to time while moving. A laser scanner is mounted in front of the vehicle (tractor, in this case) to detect the obstacle and it functions to stop the machine immediately. The other direct contact type sensor is also mounted for a double check in safety. Three-way sway of the vehicle, namely pitching, yawing, and rolling, reduces accuracy. It is also possible to control the automatic guidance operation of a group of vehicles consisting of multiple vehicles while maintaining a master-slave relationship. Figure 5 compares agricultural and industrial robots.

Difference between Industrial and Agricultural Robots

No.	Item	Agricultural robot	Industrial robot
1	Robot motion	Move to work Search, Find, Identify, Off road	Stay and wait for the work
2	Objective work	Non standardized Size, Color, Shape, Maturity Hardness, Location	Standardized Designated set position
3	Operation	Autonomous	Program based
4	Function	Learning	Teaching
5	Structure	More complicated	Comparatively simple

Figure 5. Difference between agricultural & industrial robots

C. Green Factory

This type of farming is different from the conventional one mainly focusing on the mass production of fresh market crops such as lettuce, mini tomatoes etc., which is similar to the industrial crop cultivation under completely controlled conditions of the environment. This is basically managed on hydroponic system, therefore, water is normally used for fertilizing and circulated for saving. Disease infection is tightly controlled. Workers are strictly forced to wear special work clothes, masks and caps, in addition to special work boots and gloves. The environment is similar to the clean room of semi-conductor industry plants. They are also strictly forced to take air showers when getting in and out of the facility.

Figure 6. Various types of Green Factory.

Figure 7 shows the advantages of green factories in terms of materials and costs, including future business prospects.

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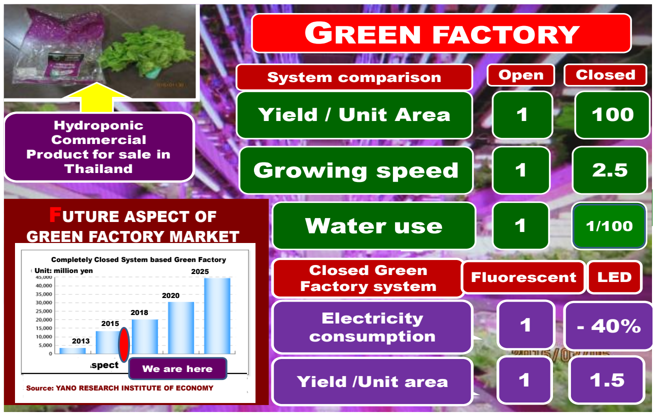

Figure 7. Green Factory, present and future.

D. Drone

Recently, the number of possibilities of drone application to the agricultural sector have grown rapidly. One of the most important merits of applying drone is to get a wide bird eye view photo which enables to find how the crops are growing. Farmers can find what and how they can do from the image sent to their device, such as a smart phone They can make decision regarding how much fertilizer should be applied from the green color image (NDVI, Normalized Difference Vegetation Index).

$$NDVI = (NIR - RED) / (NIR + RED)$$

where NIR – reflection in the near-infrared spectrum
RED – reflection in the red range of the spectrum
According to this formula, the density of vegetation (NDVI) at a certain point of the image is equal to the difference in the intensities of reflected light in the red and infrared range divided by the sum of these intensities. This index defines values from -1.0 to 1.0, basically representing greens, where negative values are mainly formed from clouds, water and snow, and values close to zero are primarily formed from rocks and bare soil. Very small values (0.1 or less) of the NDVI function correspond to empty areas of rocks, sand or snow. Moderate values (from 0.2 to 0.3) represent shrubs and meadows, while large values (from 0.6 to 0.8) indicate temperate and tropical forests. Crop Monitoring successfully utilizes this scale to show farmers which parts of their fields have dense, moderate, or sparse vegetation at any given moment. Simply put, NDVI is a measure of the state of plant health based on how the plant reflects light at certain frequencies (some waves are absorbed, and others are reflected). Chlorophyll (a health indicator) strongly absorbs visible light, and the cellular structure of the leaves strongly reflect near-infrared light. When the plant becomes dehydrated, sick, afflicted with disease, etc., the spongy layer deteriorates, and the plant absorbs more of the near-infrared light, rather than reflecting it. Thus, observing NIR changes compared to red light provides an accurate indication of the presence of chlorophyll, which correlates with plant health. Drone can be used for many other ways, such as seed broadcasting, fertilizer and chemicals application. In these cases, the payload is the problem, namely, how much it can carry and fly. More applications are under consideration; however, the challenges are security, privacy, various regulation and the standards. Hackers can break into seemingly safe remote-controlled engines and networks that control brakes and steering.

III. TECHNOLOGY APPLICATION IN AGRICULTURE

A. Nano Technology

Carbon Nano Fiber is famous and well know for its light weight and strength. It is already used for the aircraft and car industry. Recently, the bio-based Cellulose Nano Fiber is attracting a lot of interest. It is a newly developed material by Professor Hiroyuki Yano, Humanosphere Research Institute, Kyoto University, Japan from bio-resources equipped with unique physical properties, namely, 5 times stronger and 1/5 lighter than metal, in addition to higher heat resistance. The Cellulose Nano Fiber may take the application area and replace CNF (Carbon Nano Fiber) in the future. In addition, it costs 1/6 of the cost of carbon nano fiber. Cellulose Nano Fiber can be produced not only from trees, but also from various popularly known cellulose materials such as wood, rice straw, cassava and potato.

Various Nano Bubble water provides other hopeful possibilities, such as

・Oxygen Nano Bubbles
・Ozone Nano Bubbles
・Nitrogen Nano Bubbles

The applied industrial sector is shown below.

・Food safety – Vegetable sterilization
・Aquaculture (Fishery) – Oyster sterilization
・Dentistry – Periodontology / Periodontics
・Medical science - Cancer cell control

Oxygen nano bubble water has higher effect of promoting plant growth and shortening the total growth period. Ozone nano bubble water functions effectively for sterilization for various bacteria and fungi. In case of washing out the chemicals attached to agricultural products, 80% are removed by using ozone nano bubble water, whereas only 20% can be removed at one time with ordinary water. Toothpaste water using ozone nano bubble water has been commercialized. Periodontal bacteria in the mouth can be sterilized just by gargling without brushing your teeth.

B. Plasma Technology

Plasma technology can be used to treat waste and change to energy because under high temperature treatment hydrogen can be produced. On the other hand, if the plasma treatment was done under low temperature, waste oil can be changed into fuel. According to the news currently televised, it is said that around 4,000 workers are working everyday at Fukusima nuclear power plant, however it will take 40 years more to remove the debris left in the reactor. The use of plasma is promising for treating highly radioactive debris.

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C. Pattern / Face Recognition

The combined technology of image processing, pattern recognition and Artificial Intelligence (AI) is getting popularly applied to recognize and identify the individual person quickly. This technology can be used even for the individual livestock management. Two kinds of memory can be found and considered: one is a tag attached to a part of the body like a ear, and the other is the chip type to be embedded in the body. The pedometer, the route traveled, the distance, etc. are automatically recorded and sent to the data center for recording. These data can be used for observing the health status of individual livestock and managing the amount of food to feed.

The net pattern of melons is unique and original to each individual and resembles a human fingerprint. By recording and memorizing this net pattern as an image, the historical background of the melon can be known such as the place and when it was harvested and how it came from the production site. This is one of the areas called Agribiometrics or Bioinformatics.

IV. Projects and Business

In this section, we list some of the ongoing projects and businesses.

A. Blue fin tuna, Kinki University

Blue fin tuna is one of the most popular big thick fishes served at higher class restaurants in Japan. However, to meet the customers demand, fishermen must live away from home for months in remote pelagic fisheries. Sometimes the weather is unseasonable, and they sometimes encounter storms and typhoons. Some of them will also encounter a fatal accident. If they do not have to live away from home for fishing, it will make them more relaxed and even their family will feel more at ease. Fisheries should be changed from going away and fish for months to keeping put and growing fish. The Kinki University succeeded in the cultivation of blue fin tuna to grow from the stage of egg up to the final stage for shipment. Currently, blue fin tuna cultivated in this way is delivered to large cities and rural areas and is also served in the cafeteria on the university campus [4].

B. Osaka Prefectural University

Osaka Prefectural University is one of the first universities in Japan to succeed in researching and commercializing a Green (plant) factory. Just like Kinki University mentioned above, it can be said that this university has demonstrated the industrialization of agricultural products production. The cultivation shelves lined up in an environmentally controlled building are fully covered with LEDs of various colors, and the workers working inside seem to be working in the clean room of a semiconductor manufacturing plant, and they are nervous about bringing in pathogens from the outside. Harvested lettuce and other fresh vegetables are delivered not only to university cafeterias, but also to large cities and regions on order. One of the important factors to keep in mind is that producers have a clear and reliable relationship with consumers [3].

C. EUGLENA Project

This is a joint venture project already launched few years ago. The author does not know how much they have been successful up to now unfortunately, however, this business model is one of the few successfully launched examples the author knows about. The main product is an alga. Euglena has many characteristic features, but it is noteworthy that it absorbs a large amount of carbon dioxide. Electric power plants discharge a large amount of carbon dioxide, which can be absorbed by Euglena to promote its own growth. The produced Euglena can be sold as a raw material or resource for food, feed and fertilizer, while also contributing to aircraft jet fuel as bio-fuel. The problem with business operations is that they need technology to produce a large amount of Euglena in a short period of time, and the company founders have also proven this technology. Since it is a bio-based fuel, it contributes a lot to a low carbon society and decarbonization from the viewpoint of carbon neutral concept [5].

D. Good Harvest Plan

This is also a business model proposed by Toyota. It is a contractor-type business model for small-scale farmers or farmers who have no successor, but own farmland. The farmer will contact the contracted center and request the dispatch of machine together with driver to carry out the necessary operations timely. The center will respond to the request by dispatching an appropriate driver according to the type of farming operation. The main operation is tilling, transplanting and harvesting, but the farmer is the owner of the farmland, however, does not physically work directly. The number of such contractor-type farmers is increasing in Japan due to no successor. Agriculture in the high-tech and information era has the potential to significantly increase the entry of industries from completely different sectors that are not closely related to agriculture [7].

E. Animal Factory

This is an animal version factory of a plant factory. The target livestock are dairy, beef cattle, pig farming, and poultry farming, but unlike growing in a limited space, this is a project to give time to walk around freely in a wide space and to carry out breeding management of livestock with high quality meat. Individual management using small device and equipment incorporating information and communication technology is extremely needed. The necessary information is sent as data from sensors attached to dairy cows and beef cattle grazing in the pasture to the central center and used for individual health management.

F. Beef Traceability

It was already mentioned above how important the mutual liability between producer and consumer. Food security has four important keywords such as 2QSL consisting of

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Quantity, Quality, Safety and Liability. One of the most important problems, but difficult one to negotiate, is the mutual liability issue. No matter how famous and well-known companies are, if they do not manage well, they will disperse false information. They can cheat the place of production, fake the contents of the product, rewrite the expiration date, and do embarrassing acts without hesitation. The other three conditions except mutual liability are relatively easy to clear and satisfy. This is because there is no problem as far as the standard code level is cleared.

G. International Collaborations

Asia can be qualified as a world food pantry in production and supply, however, farmers are still working in poor conditions due to various problems such as family labor and low income mainly caused by small scale farming. The ASEAN community based international collaboration is really needed in technology transfer and human resources development. Technology oriented countries should join and actively invest in Asia for further economic promotion and regional peace keeping. The author is making a proposal named FFA (Future Farmers of Asia).

V. CONCLUSION

Global tetralemma is a common issue not only in Asia, but also in the world, and these issues must be resolved urgently.

Asia is qualified as a world food pantry capable of producing and supplying huge amounts of food. However, although the production is large, the quality of the products is not constantly controlled. From the perspective viewpoint of food security due to the rapid increase in the world population, technology-oriented nations should actively invest in Asia through technology transfer and human resource development. A collaboration system in which technology-oriented countries provide technology and resource-oriented countries provide resources is effective in solving mutually common problems. In other words, avoidance of food crisis, escape from hunger and poverty, and promotion of regional economy bring regional peace keeping and its stability. Agricultural policy is not about providing farmers with financial support to increase their income. It is more important to have a policy to strengthen the agriculture industry rather than supporting farmers. If such a policy is continued, there can be no promotion of agriculture. In Japan, a rice production control policy was implemented for half a century, but, as a result of that, agriculture has declined significantly rather than being promoted. Although the aging of farmers will come sooner or later, looking down on the agriculture industry has brought about a serious situation where young successors are not interested in continuing in that sector. Given that industry is production-based, production control is not an option. Rather, the basic principle is to focus on developing new markets and increasing consumption.

Food is an indispensable resource for human survival, and the prosperity of agriculture-based Asia is important and necessary not only for Asia, but also for the world. The IT based high-tech agriculture provids the opportunity for many kinds of industries to join and invest in agriculture.

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