Natural resources based integrated agricultural system for the sustainable plantation industry

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Abstract. Crop production is the management of plant environmental factors to achieve maximum and sustainable production. Thus the production of crops in an integrated agricultural system must be capable not only to integrate and to harmonize between commodity components, various species of crops and livestock, but also to integrate and harmonize these commodity components with various elements in every environmental factor, both biotic and abiotic. The integration and harmonization based on renewable natural resources is an effort to realize a sustainable plant production (for profit, for people and for planet). Two groups of environmental factors grow plants, namely Abiotics: Climate and Edafik (land), and Fire; And Biotics: Disruptive organisms (pests, diseases and weeds), beneficial organisms (land coverage vegetation, bacteria and non-pathogenic fungi, symbiotic). Climate and soil factors are the two main factors interacting with the changing environmental factors of crops as a result of climate change, whether global, local, or micro. These changes have been identified to be environmental stresses for plants. Abiotic stresses of temperature, water and nutrients provide a weakening condition, thereby increasing the vulnerability of plants to biotic stress. Various efforts need to be continued to develop integrated agricultural production technology that utilizes local natural resources to enable plants to adapt to environmental stress. Below, Integrated agriculture system will be describe into on-farm subsystem (horizontal diversification) and off-farm subsystem (vertical diversification).

1. Introduction

The above-mentioned climatic changes provide abiotic stress to the plant, which then either quickly or slowly may cause biotic stress. The suboptimal abiotic growing environmental conditions above provide the stress that inhibits growth and decreases the productivity of the plant, which then causing plants to be more vulnerable to biotic stress, especially soil borned diseases.

The above environmental stress measures can be overcome in various ways, including:

- Genetically using plant material from varieties that are tolerant to drought stress and resistant to biotic stress, especially soil borned diseases and waterlogged. Breeding activities toward developing varieties that adapt to environmental stresses need to be further improved.
- By applying integrated agricultural production technology. The production technology must be capable of:
  a. Increase crop adaptability to drought stress and low nutrient availability, low light intensity and waterlogged;
b. Ameliorating the soil properties of these limiting factors, namely by improving the ability of soil to retain water and cation exchange capacity, and increasing the availability of nutrients for plants;

c. Efficient use of inputs made from raw materials "non renewable resources" as cultivation energy and utilize the phenomenon of mutualism symbiosis between components of integrated agriculture

- **Sustainable Agriculture Production System** supported by agronomy technology based on natural resources which:
  
a. Environmental-friendly and efficient (LEISA principles, Low External Input Sustainable Agriculture) soil and nutrient conservation technologies by reducing leaching and run-off; Conservation of water and other natural resources; Making use of the alignment in differences in width and height of the canopy, as well as the depth and distribution of roots, from tree plants, shrubs, to soil cover plants.
  
b. The diversity of species in integrated agricultural components creates a growing environment that increases the diversity of biological resources, both above ground and in the soil. Such environments allow for a symbiotic and synergic relationship between organisms, both macro and microorganisms
  
c. Increase productivity and provide economic and social-friendly added value (for profit and for people)
  
d. Integrated agriculture system, horizontally and vertically.

2. **The role of agronomy in sustainable development**

The development of the concept of Integrated Farming System (IFS) will require the development of excellent and integrated research, both for scientific development, and applied technology that need to be supported by several fields of science, especially Agronomy, Soil Science, Plant Protection and Socio-economics, recognized as Sciences in Agriculture. The development of the IFS concept needs to be supported by human resources that have excellent competence in these branches of science [6]. The role of the Indonesian Agronomy Society, as a set of agronomic professions has a great responsibility to be able to contribute, both in the development of agricultural education and in the development of sustainable agricultural technology. In relation to the development of integrated and sustainable agricultural systems, deep research is needed in each branch of related science, but is integrated in its implementation by including sustainability variables. Several scopes of research through an integrated approach are presented below as follows:

- Technology of conservation of soil and water resources with vegetative method to increase water availability and minimize water stress during dry season, increase nutrient absorption and plant assimilation capacity
- Development of water-saturated culture techniques and improve the ability of plant adaptation to waterlogging stress, as well as controlling the environmental limiting of edaphic factor.
- Utilization of on-farm and off-farm waste to increase organic materials and the availability of ground water and fertilizer efficiency, and its substitution to artificial fertilizers.
- Utilization of host plants and inoculation of mycorrhizal and phosphate solubilizing bacteria, as well as other beneficial microorganisms to accelerate waste decomposition and improve fertilizer efficiency, plant adaptability to abiotic and biotic stress
- Utilization of organisms (natural enemies) is advantageous in Integrated Pest Management, antagonistic properties of microbial species against disease pathogens and predatory organisms against pests.
- Management of plant-specific intercropping canopies and varieties as an effort to optimize the utilization of solar radiation, water and nutrient, and simultaneously to overcome environmental stresses; mean while also increasing the biomass production of different types of plants in a multi-story canopy system.
- Horizontally integrated agriculture, which is related to research and development of integrated farming system, supported by soil and water conservation measures; Which combine livestock subsystems and plant subsystems in a mutually beneficial relationship (eg, secondary crops and livestock feed crops as intercropping plants in intercropping cropping pattern under immature and mature of tree plantation, such as coconut and palm oil plantation areas; Agroforestry: agrosilvopastoral, agrosilvofisheries. The vertical integration, that is, the utilization of waste for industrial products is important.

3. Development of production technology

3.1. Utilization of natural resources, soil microorganisms and organic matter

3.1.1. Abiotic environmental improvement technology. The roles of soil microorganisms (eg mycorrhiza, N-fixing bacteria, phosphate solubilizing bacteria) will be illustrated. Some researches and development have shown the role of soil microbes, either independently, or symbiotically with plants and / or with other microorganisms. The role may be an improvement in the supply of nutrients and its absorption by roots, and may also increase water absorption in drought stress conditions.

Both ultisol and coal mining areas have low fertility and water absorption problems, resulting in drought stress in the dry season. such conditions are needed to be improved. Reclamation is an activity undertaken to improve marginal lands (Ultisol and post-mining) which is then followed by revegetation activities. Revegetation itself aims to restore the physical, chemical and biological conditions of the soil. However, improvement efforts in this way are still perceived as less effective, this is because the plants are generally less adaptable to the extreme environment, including the former mine land. To overcome this situation can be done in several ways, namely: 1) the addition of soil ameliorants such as lime and humic acid. 2) the use of types of plants tolerant to aluminum which is an adaptation of plants to suboptimal conditions on Ultisol, 3) The potential use of soil microorganisms and friendly environment are often referred to as a biological fertilizer were first selected at high Al soil condition. The soil microorganisms are: Arbuscular Mycorrhizal Fungi (AMF), phosphate solubilizing microorganism (PSB) and nitrogen-fixing bacteria (Azospirillum).

One alternative to overcome this problem is the use of beneficial microorganisms that arbuscular mycorrhiza fungi (AMF) is capable of symbiotic relationship with almost all types of plants, the plants will be helped in absorbing water and nutrients in the nutrient-poor soil as the land of mines tailing Petroleum and coal and Ultisols. The development of AMF in each land area is different and its effect on plants is also different, so it is necessary to apply the AMF isolate that suitable to environment and cultivated plants [10][24][21].

Nutrients are absorbed by plants infected by AMF especially P, because P is needed in relatively large amounts, but its availability is mainly on acid soils to be limited so that it is often a limiting factor in increasing crop production. Additionally, mycorrhizal infected roots increase the absorption of NH4 + and NO3- and Mg.

With similar handling patterns to the suboptimal growing environment, Panca Dewi Manu Hara Karti started with a dissertation research on livestock feed crops. [11] studied the mechanism of tolerance of Setaria splendida against Al toxicity and the role of soil microorganisms in increasing the solubility of soil phosphates

In the plant species and environmental conditions of other growth media, in his dissertation research, Iwan Sasli also reveals the role of FMA in Aloe vera plant, on Histosol or peat soil in Pontianak, West Kalimantan. FMA applications have also managed to improve the growth and quality of Aloe vera plants and at the same time increase the efficiency of fertilization in peat soils [17].

3.1.2. Interaction of abiotic and biotic environmental factors. The role of FMA that has been described above will generally improve the abiotic growing environment, including the role in the availability and absorption of nutrients, especially phosphate, enhancing the ability of plant adaptation to abiotic stress of drought, and abiotic stress of heavy metal toxicity. It is generally assumed that the morphological and
physiological improvements of the plants, especially their roots, caused by the inoculation of FMA resulted in the plant growing with a vigour growth, thus more able to cope with biotic environmental stress, ie pathogens, the cause of plant diseases. Nevertheless, the results of Yenni Bakhthiar's dissertation research reveal the other sides of the interaction between abiotic environmental factors, biotic environmental factors and oil palm crops [4][5], and on cacao nursery [18][19].

3.2. Growth media improvement

Various opportunities on development of production technology based on the phenomenon of genotype response diversity, because of the diversity of plant genetic against suboptimal environment. Technologies that can be developed primarily aimed at improving the ability of plants to adapt to environmental stresses.

Improvement of plant growth medium can also be done by giving organic ameliorant. Organic acids are biosynthesized in plants by the roots and then be exudated in to growing media to improve the plants to adapt on stress. The mechanism is then used as the basis on developing production technology by utilizing friendliness of natural resources in the form of organic acids naturally produced. Organic acids also can be derived either from the decomposition of organic matter, produced by soil microbes, including arbuscular mycorrhiza fungi (AMF) and phosphate solubilizing bacteria, and produced or available in nature in the form of water-containing organic acids, such as peat water. Hastin Ernawati Nur Chusnul Chotimah on his dissertation research revealed the role of organic acids in overcoming Aluminum stress in acid soil (Al-dd high, 20.60 me / 100g) in Aloe vera plant. Organic acids are naturally available in peat water [7][8]. Ameliorant of peat water improves plant growth and positively affects nutrient P in root and leaf frond. Of the various organic acids, phenolic acid derivatives dominate peat water, the application of phenolic acid and Al, stimulates Aloe vera plants to accumulate oxalic and malic acids.

Bio-charcoal significantly improved the phosphatase acid activity of growth medium, organic fertilizer significantly increased the soil pH, phosphatase acid activity, and available P, reduced soil exch. Al, improved growth, dry weight of cacao seedling, and uptake of nutrients of P, Ca, and Mg of the cacao seedling. Incubation of MPF B. ambifaria B-SS1.2 dan A. niger F-E1, also significantly increased the dry weight of shoot of the seedling [18][19].

The research results using peat water ameliorants as tried above, developed through other dissertation research by Hesti Pujiwati in tidal mineral soil. The application of peat water of peaty mineral soil managed to increase the adaptability of black soybean plants to aluminum stress in Water Saturated Culture, in Banyuasin, South Sumatra [14]. The organic acids contained in the ameliorant used successfully suppressed Al toxicity in the plant. This result shows the opportunity to grow the annuals and perennials as intercrops under the coconut palm plantation of similar land condition.

3.3. Utilization of plant resources diversity

In the nature there are many different types of plants that can be utilized in the improvement of the plant growing environment or directly to improve the efficient use of cultivated land. Cultivation of ground cover and intercrops is an activity that has been done in many plantations, including coconut palm plantations. Ground cover crops are grown aiming to support the growth and development of palm more optimally, especially in creating a better microclimate. The microenvironment includes soil conditions and climate around the palm. Good growth environment ideally will produce plants that have optimal productivity.

The study of planting cover crops on plantation land is more emphasized on its function as a land and water conservation crop. The soil cover function is usually aimed at open areas, not covered by the main plant canopy, ie in the area of young plants or immature crops, so that the function of covering the soil is considered unimportant in the cropping of the canopy. The results of two dissertation studies indicate some of the functions of other ground cover plants, especially in the area of mature palm trees, whose canopies have been mutually closed [25][26][1][2]. The ground cover vegetations were able to
increase the groundwater reserves, resulting in more groundwater availability and shortening of groundwater deficit periods. These results indicate the increasing need for us to change our understanding of weeds and ground cover vegetation. A species considered weeds in annual crops should not also be considered weeds under perennial crops, where they have much shorter life cycles and cycles than the main crops are long-lived palm, (25 years). Thus the species is more acting as a ground cover. So is the case with the ground cover, the old paradigm and possibly still going on now, with the understanding of the role of the ground cover confined to the control of erosion and weeds in the area of immature tree plants, so that in the mature trees plant area that the canopy has been closed, it is no longer necessary to cover the soil. Meanwhile, sustainable agriculture systems (eg, coconut palm plantations), soil cover vegetation also contribute to sustainability variables, which is to reduce greenhouse gas emissions by fixing them and increasing carbon stocks and biodiversity, as well as improving water and nutrient balance.

3.4. Optimizing the utilization of agricultural resources for sustainable production technology

Increasingly limited agricultural land resources, quantity and quality and increasingly uncertain climatic conditions require efficient and effective management to retain high and sustainable agricultural production in order to meet increasing food and energy needs. Land needs to be maximally utilized, changes in climatic elements to be followed by the application of sustainable production technologies those are characterized by appropriate and efficient use of inputs.

Optimal land utilization can be done, among others, by intercropping system, intercropping plants between tree crops or perennials, and development of integrated farming system. The land use model for intercropping cultivation is disclosed through dissertation research, as conducted by [22] in maize and cassava by minimizing competition among species has provided useful information in planning proper production at the field level. By incorporating the soil physical characteristics and climatic elements, a model can be used to predict growth and production on different soil or climate conditions. [15] has developed a model of soybean growth under shady conditions. With shading percentage input, a / b chlorophyll ratios, light compensation points, groundwater content at field capacity, moisture content at permanent wilting point, and agroclimatic data have produced models to predict the growth of soybean plants under shade.

Optimization of land use with integrated farming system also needs to be designed in such a way as to obtain the type of commodity and scale that can provide sustainable ecological and economic feasibility. The design of integrated farming models of crops and / or crops on a limited area of agricultural land (0.20 hectares) as did [23] can be expanded more widely for proper production planning.

Intercropping system with three seasons of intercropped plants, corn and soybean on immature of replanting oil palm plantation area has been studied by Kusumawati (PhD dissertation, IPB 2019). Another research also has been reported on intercropping system with feed crop of Indigofera zollingeriana grown under mature oil palm plantation [16].

Model of intercropping system on oil palm plantation replanting area has been studied through PhD-dissertation research [13]. The sustainability measurements were conducted to valuate several sustainability variables as the criteria of sustainable crop production system. Ecologically sustainable and economically feasible were measured, where the results are as follow:

1. The amount of CO2 emissions during the replanting process in differsent landform shows as follow, CO2 emissions from land under the 28 years old oil palm stands before land clearing at 28.5 t CO2 ha⁻¹ year⁻¹, on bare land after land clearing at 59.0 t CO2 ha⁻¹ year⁻¹. Emissions on intercropping plants were 49.3 t CO2 ha⁻¹ year⁻¹ and in 1-year-old oil palm were 42.9 t CO2 ha⁻¹ year⁻¹. The CO2 emission reduction occurs in addition to most of the CO2 produced is reabsorbed by plants for photosynthesis, also because it is stored in plant biomass as carbon stocks were as follows 10.2 t C ha⁻¹ of corn plants; 7.6 t C ha⁻¹ of legumes, 3.5 t C ha⁻¹ of soybeans, 2.8 t C ha⁻¹ of natural vegetation, and 42.9 t C ha⁻¹ of 28 years old oil palms.
(2). Corn productivity of planting season 1 to 3 consecutively are 5.01 t ha\(^{-1}\), 7.51 t ha\(^{-1}\) and 6.57 t ha\(^{-1}\), or an average of 6.36 t ha\(^{-1}\). Soybean productivity is 1.60 t ha\(^{-1}\), 1.28 t ha\(^{-1}\) and 2.19 t ha\(^{-1}\) or average 1.69 t ha\(^{-1}\). The average value of R/C of corn is 2.66 and soybeans are 1.33, so both are feasible to plant

(3). The sustainability status of the intercropping model on smallholder oil palm plantations in Pelalawan Regency, Riau Province was viewed from 5 dimensions, namely economic dimensions with index 60.02, social culture 65.22, technology 59.45 and institutional 56.23 including fairly sustainable categories, while environmental dimensions 85.31 are categorized as sustainable.

3.5. Plant improvement in accordance with integrated farming system.
Plant improvement through plant breeding and eco-friendly natural resource management is essential to sustain crop production from environmental stress of rapid climate change. It is also important to consider that climate change risks include not only direct impacts on crop production, but also on long-term degradation and ecosystem conservation issues for soil, water and biodiversity. Therefore an approach based on natural resources friendliness and crop production management in accordance with anticipatory goals for adaptation is a necessity. An important example in this regard is the use of various microbes that have a positive role in negating or reducing the impact of climate change is necessary. Exploring knowledge and discovering and implementing microbial use technologies for integrated agricultural development need to be done continuously.

Moving forward, the development of plants that have the double resistance to climate-induced stress and its resource friendliness based production technology will be critical. For example, for saline environments, rice varieties must have high temperature, salinity, and inundation resistance, and adapt to integrated agricultural ecosystems to achieve a sustainable tolerance of climate change conditions in the future, will be more dramatic. This is a great challenge for physiologists, genetic and plant breeders.

3.6. Vertical integration – diversification of products, coconut palm as the case
The trigger of coconut problem in Indonesia is related to the less competitiveness of coconut main product ie copra, raw material of vegetable oil (cooking oil) compared to palm oil. In good garden conditions, the productivity of coconut oil only reaches less than 2.0 tons of oil per hectare, while palm oil reaches 5 tons of oil per hectare. This condition is getting worse, because the productivity of plants is also declining. The situation is becoming worse for the upstream sector of coconut plantations, especially the smallholder coconut, as it is shown by the declining on productivity and national coconut production.

Agribusiness and agroindustry are needed to be developed, in addition to sustainably improving the quantity and quality of coconut production subsystem, in an integrated agriculture system that should also be able to diversify products (vertical integration) to improve the economic value of processed coconut products. From a coconut fruit can be obtained coconut water (raw material for making drinks and nata de coco), shell (active charcoal), beans (coconut milk, coconut, coconut oil), cake (from coconut meat and epidermis), brown coir fiber, white coir fiber, coir fiber, oleochemical (coconut derived products). (Ambar, sustainability, roles of intercropped system on, status)

3.7. Horizontal integration – intercropping system, oil palm a proposed case
Future development of intercropping systems on oil palm plantation are proposed as follow

- The intercropping system is still be possible to be developed in the future to support the sustainable plantation industry. The purpose should be the optimization of farm income, land utilization, encouraging the farmer creativity, anticipating lower/dropped fruit bunch price, and black campaign on oil palm industry.
- The limiting factor for intercropping system under oil palm canopies are shade (lower light intensity) and limiting growing space, due to, circle weeding area, and life inter-row for mechanical fertilizing and harvesting.
• As consequences, the intercropped plant species should be shade tolerant and easier to manage (not complicated and less intensive culture) for small farmers.
• The intercropping space areas are mainly and only on dead inter-row. Planting space arrangement with a wider planting spaces, above 9 m x 9 m x 9 m or a double row system (a wider dead inter-row than life inter-row called legowo system), or with lower palm population density of less than 130 palm per ha or planting new varieties with shorter leaf frond or smaller canopy in order to increase the intensity of light portion for intercropped under the palm stands. So that, there are dynamic intercropped species (according to the level of tolerance to shade, lower light intensity), along with the increase of oil palm ages, as the main crops.
• Several species of plants those have been usually grown under the shade tree plants, such as plantation crops, coffee and cacao, green feed crops, such as Indigofera zollingeriana), Asystasia gangetica, elephant grass (Pennisetum purpureum), and others

The development of agro-industry in an integrated agriculture system that directly involve farmers through the development of integrated household-based coconut (plantation crop agribusiness. Integration includes the scope from upstream of integrated on-farming sub-system (raw material and waste production) to downstream of integrated off-farm sub-system (processing and marketing of products), partnerships between household based and large-scale agribusiness, cooperation between Academician, Business, Government and Community (ABGC). In this case, each party working together is IPB (academician), Indonesian Coconut Board / Businessperson, Directorate General oh Estate Crop / related agencies (government) and farmer household-local traders (community).

4. Closing remarks
The increasingly widespread agricultural area with the suboptimal growing environment, both because of the increasingly marginal land, and because of climate change. The sustainable production technology that needs to be constantly developed is genetically using plant material from varieties that adapt to environmental stresses and location-specific cultivation technology

Sustainable production technology in integrated farming systems is developed by utilizing natural resource friendliness to improve the crop adaptability to environmental stresses and use renewable and external inputs efficiently and effectively.

The implementation of integrated agriculture system from upstream on-farm sub-system (horizontal diversification) to downstream off-farm sub-system (vertical diversification) should improve the sustainability and competitiveness of coconut palm and oil palm industries involving the sustainability variables or measure to insure the benefit of any system or technology to support Sustainable Plantation).

Integration should includes the improvement of farmer institution, partnerships between household based and large-scale agribusiness, and support from cooperation between Academician, Business, Government and Community (ABGC)

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