Study of dryland cultivation farming technology to support sustainable food independence on small islands

J Riry¹,*, A S Mahulette¹, A M Tapotubun², W A Riry³

¹Agrotechnology Study Program, Faculty of Agriculture, Universitas Pattimura, Ambon, Indonesia
²Fisheries Product Technology Study Program, Faculty of Fisheries, Universitas Pattimura, Ambon, Indonesia
³Law Study Program, Faculty of Law, Universitas Pattimura, Ambon, Indonesia

* E-mail: riryjohan@gmail.com

Abstract. The agricultural sector's strategic roles for economic growth, including, among others: providing food for the Indonesian population, earning the country's foreign exchange through exports, providing industrial raw materials, increasing employment and business opportunities, increasing regional revenues, and alleviating poverty. The Food and Agriculture Organization (FAO) stated that food self-sufficiency occurs when everyone in every moment can access food both physically and economically to meet their daily needs. Drylands have characteristics such as water shortage, erosion sensitivity, low land productivity, high variability in soil fertility, limited plant species, low adoption of advanced technology, minimal capital availability, and inadequate infrastructure. Small islands are islands ecologically separated from the mainland island, have clear physical boundaries, and are isolated from the parent island's habitats, so they are insular. Small islands usually have relatively small catchment areas, are vulnerable to global warming, sensitive to natural disasters, isolated and far from the main market, open to small-scale economic systems, have high population growth rates, have limited infrastructure and education, and limited skills of its inhabitants. Small islands have a high rate of land degradation that threatens the long-term sustainability of agriculture. Technologies that can be applied to dryland on small islands are conservation farming, LIESA system, Biointensive Gardening, Dusung, Agropasture, Sloping Agricultural Land Technology (SALT), Rounders type, No-tillage, and small island weed management. This paper is an ideal contribution to overcome the food problem in small islands that generally have drylands. It was presented at the National Seminar of the Indonesian Agronomy Association (PERAGI) in Bogor

1. Introduction
Based on Law No. 18/2012 of the Republic of Indonesia, food is defined as anything that comes from biological sources of products from agriculture, plantations, forestry, fisheries, livestock, aquatics, and water, both processed and unprocessed which are designated as food or drink for human consumption, including food additives, food raw materials and other materials used in the process of preparing, processing and/or making food or beverages. Food sovereignty is the right of the states and nations, which independently determines the food policy that guarantees the right to food for the people and gives the community the right to determine a food system following the potentials of local resources.

The food conditions of a country significantly affect its stability. The food problem is a crucial problem because it is directly related to various groups of people. Food determines the people's life and death; that was the statement of the first President of the Republic of Indonesia (Sukarno) when he...
laid the groundwork for the IPB campus in 1953. We have passed 64 years, and the food problem is still a serious problem to be discussed and developed. The indication from the world's food organization (FAO) concerning the possibility of a world food crisis in 2025 has prompted agrarian countries to struggle to utilize food resources to meet their country’s food needs. With a population growth of 1.6% per year, this includes Indonesia, a severe burden for its food supply. The government policy about rice commodity as a food source has resulted in the staple food pattern of the previously diverse people (rice, sweet potato, corn, sago, banana, etc.) according to local potential and culture, now experiencing changes that tend towards a single staple food pattern—namely rice [1].

Adequacy of food is the right of every human being, which means that everyone has the right not to be hungry and to have access to adequate, nutritious, and safe food for their health. Food security can be defined as access to adequate food for everyone at any time to obtain a healthy body and an active life. Food security includes food production and availability, distribution and affordability by all people, individual consumption to meet nutritional needs, and monitoring food insecurity. Weak food security can be caused by several factors, such as low production of agricultural food products that cause low supply; this factor can be caused by nature or climate that is not supportive and mismanagement of agricultural food production and natural and human disasters. Also, dependence on one type of food, changes in earth temperature, and new food pathogens can cause weak food security [2]. Food and family economic needs encourage the community to continue to manage land with shallow solum, rocky lands, narrow and terraced fields, and steep slopes with hilly and mountainous terrain. Not only that, they use dry areas with wet months of only 3-5 months, which is enough to plant corn or other crops. If there is no better alternative, any land will be utilized; that is the community's choice to maintain and fulfill their daily needs [3]. The government's policy to boost food self-sufficiency that promoted rice has resulted in increasingly narrow food diversity. Lowland paddy requires much water, a good permanent irrigation network, and generally requires a high initial cost. The policies that lead to one type of food have caused other types of food to experience degradation, especially local food, to decline so that areas experiencing rice shortages will be called food insecure areas, even if local food sources are quite abundant.

One of the causes of low food production in Indonesia is decreasing productive land availability due to land conversion, use of productive lands as locations to build factories, housing, sports facilities, and other public facilities. In Indonesia, it is estimated that there is a loss of productive lands of approximately 23-25 thousand hectares every year. In addition to land conversion, many lands are classified as marginal due to limited nutrients, rocky structure, and many of them are acidic soils [4]. With the decreased agricultural land in Indonesia, it is not easy to expect the farmers to produce optimally [5]. Apart from the problem of agricultural land availability, climate change has also affected low agricultural productivity. Global climate change has become an important issue and attracts attention.

Table 1. Drylands that are suitable for agriculture in Indonesia

| Province            | Lowlands (ha) | Highlands (ha) |
|---------------------|---------------|----------------|
|                     | Annual         | Perennial | Sum.  | Annual         | Perennial | Sum.  |
|                     | crops          | Crops     |       | crops          | Crops     |       | Total |
| Sumatera            | 4,899.476      | 15.848.203| 20.747.679| 1.103.176    | 992.055   | 2,095.231 | 22.842.910 |
| Jawa                | 925.412        | 3.982.008 | 4,907.420 | 200.687     | 484.960   | 685.647   | 5,593.067  |
| Bali and Nusa Tenggara | 1,091.878    | 1,335.469 | 2,427.347 | 58.826      | 201.761   | 260.587   | 2,687.934  |
| Kalimantan          | 10,180.151     | 14,340.956| 24,521.107| 592.129     | 389.521   | 981.650   | 25,502.757 |
| Sulawesi            | 1,801.877      | 3,664.040 | 5,465.917 | 70.780      | 1,134.320 | 1,205.100 | 6,671.017  |
| Maluku and Papua    | 4,360.318      | 8,282.809 | 12,643.127| 43.094      | 233.981   | 277.075   | 12,920.202 |
| Indonesia           | 23,259.112     | 47,453.485| 70,712.597| 2,068.692   | 3,436.598 | 5,505.290 | 76,217.887 |

Source: Center for Land and Agro-climate Research and Development, 2001

Based on the islands' physiography, Indonesia is an archipelago consisting of large islands (Java, Sumatra and Kalimantan, Sulawesi, and Papua), medium islands (Halmahera, Bali, Timor and
Yamdena, Seram, Buru, and Tanimbar), and numerous small islands. Management of large island agriculture is different from those of small islands. In general, small islands have weaknesses in crop production. These weaknesses include the fertile soil layer is very thin, having extreme weather, and limited water resources. Also, the islands formed in a cluster of islands have different characteristics from one island to another. Some islands are located far away from each other, but they have the same characteristics (distant similarities). However, on the other hand, some islands are close to each other, but they have different characteristics (close differences).

Policymakers often ignore the utilization of dry land for agriculture since they are more interested in increasing rice production in paddy fields. This may be because there is an assumption that increasing rice production is easier and more promising than crops such as upland rice, which have a higher risk of failure. Despite the available drylands, this is quite extensive and can produce upland rice of more than 5 t/ha. Potential drylands can produce sufficient and varied staple foodstuffs, upland rice, and other crops if managed using effective technology and appropriate development strategies. The main food source is rice and corn, sorghum, soybeans, green beans, cassava, sweet potatoes, and the like, all of which can be cultivated on dry land [9]; [10].

Low production of agricultural food products causes low supply, which factor can be caused by nature or climate that does not support and mismanagement of agricultural food production as well as natural and human disasters. In conducting agricultural business on dry land, one of the important questions that arise is how to get water for crop irrigation. The irrigation system suitable for dry land is a micro-irrigation system, which uses emitters. Micro-irrigation has the main objective of making efficient use of water by plants and reducing evapotranspiration. The next upland irrigation technology is the 'jug fertigation system'.

This later system has the advantage of up to 25% fertilizer efficiency and reduces mechanical damage to crops. There are various challenges in conducting agricultural cultivation on dry land, including limited water sources, requiring plant varieties resistant to water stress, and relatively low soil fertility. This writing aims to describe the potentials for dry land technologies in Indonesia to develop food crops towards food self-sufficiency. According to (tetap harus ADA nama) [11], to be able to produce optimally and benefit farmers, planting upland rice using the SRI (System of Rice Intensification) method in dry land should be done in the rainy season because farmers do not need to pay for water supply, including rental pump machines and labor. Ultisols, oxisols, and inceptisols generally dominate dry land's soils. These soil types are generally yellow to red in color and have undergone further weathering with the content of the sand fractions, which are dominated by quartz and opaque. In contrast, the clay fractions are dominated by kaolinite, goethite, and hematite, have low clay activity, are acidic, have low nutrient contents, and a high Al saturation [12]. Organic fertilizers and agricultural wastes, such as biochar, can increase productivity on drylands [13].

2. Methods
This paper is based on a desk study and library research. The information collected relates to the various technologies applicable to dry land. This paper is also based not only on a literature review but also on the author's experience as an observer in agriculture, arid land agriculture.

3. Results and discussion
Based on identifying various agricultural problems that occur in the dry land, the discussion is directed at finding a solution for increasing crop production aimed at achieving food self-sufficiency. The discussion concerns technology offers that can be applied to solve dry land problems generally found on small islands based on the topic. Apart from the technology offered, there are also other solutions to deal with low agricultural production in Indonesia. Some simple agricultural technologies that have been implemented in Indonesia and developed in the Maluku Islands are discussed as follows:

3.1. LIESA (Low Input External Sustainable Agriculture)
LIESA system is a rural agricultural technology applied in Indonesia, especially in Maluku, since centuries ago. People only use natural resources in situ for their agricultural needs. The use of agricultural production supplies in fertilizers and pesticides from outside (ex-situ) is only slightly or even rarely done. LIESA in Maluku is classified as simple organic farming. The term simple organic agriculture is deliberately conveyed by the author to understand that between organic and inorganic agriculture, there is what is called simple organic or semi-organic farming.

3.2. **Bio-intensification (use of biological fertilizers).**

Bio-intensification or the so-called intensification of biological agriculture, i.e., by utilizing living organisms both above the soil surface, such as pollinating insects, natural enemies, and other organisms, as well as below the soil surface, such as earthworms that can fertilize the soil, mycorrhiza which can fix nitrogen from the air which in turn helps growth and crop production. Bio-intensification technology is a form of intensive agriculture that uses biological materials and environmental management to revive productive and sustainable natural agricultural ecosystems. Several technologies that use biological materials to restore natural agricultural ecosystems include planting green manure crops, alley cropping with legume crops, and crop-livestock integration (agropastoral). All these technologies provide an opportunity for the agricultural ecosystem to restore its condition to become productive again [14].

3.3. **Bio-Intensive Gardening (BIG) such as Alley Cropping**

BIG is a gardening technique widely applied in the Maluku region, especially West Southeast Maluku, by using appropriate spacing technology between staple crops and other plants that produce nutrients for the crops. Alley cropping is a planting technique that regulates plants with a certain distance between staple crops and side plants so that sunlight can be used as much as possible.

3.4. **Dusung System Agriculture (Agroforestry)**

Dusung is a food crop conservation agricultural model on dry land applied in several regions in Indonesia. Dusung is a sedentary agricultural system that optimally utilizes space, a system that has been implemented by the people of Maluku from generation to generation. This system is a complex agricultural one because it grows various crops and other plants in an area (high intercropping system). In various high-stratum plants, such as durian and canary nut, other trees to produce housing materials, such as salawaku, titi, and teak, are grown. Those are deliberately planted because they have multiple benefits, namely economic and ecological benefits. The ecological benefit is that the trees have a large stature that can withstand strong winds (wind breaks) to protect cloves and nutmeg. Besides, in the same area, cloves, nutmeg, coconut, and medium-sized fruit trees, such as longsang, duku, cempedak, jackfruit, and others, are also grown. In addition to the types of plants above, food crops, such as cassava, taro, gembili (lesser yam), and other types of tubers, as well as several types of nuts and beans, are also grown as lower-stratum (bottom) plants [15].

3.5. **Agropasturale**

The term agropastoral or mix farming that combines agriculture and livestock in the same area. The relationship between livestock and crops/plants is very close because the plants need livestock, and the livestock also needs the plants. Residues of the harvested crops can be used as animal feed. Livestock can take advantage of harvested crop residues, such as corn stalks and leaves, legumes, cassava leaves, and others. Plants need nutrients from animals; feces and urine released by animals will become good fertilizers used by plants..

3.6. **Sloping Agricultural Land Technology (SALT)**

SALT is a farming system that is suitable for use in areas with sloping land conditions. In this system, plants are planted in a contour following the direction of the slope, the plants are arranged in such a
way as to hold water when it rains, thereby reducing the impact of erosion that can make the soil critical due to soil degradation.

3.7. **Rounders Type (with Crop Rotation)**
Rounders type is a system developed from the agropastoral system. The agropastoral has a small land area, and the livestock can move around. On the other hand, the rounders type has a larger area, the number of plants is more, and the pen system is fixed in the middle. Plants are grown in rotation alternately between forage crops (fodder) and food crops (human food) [16].

3.8. **No Tillage or Minimum Tilage (TOT or OTM) by using a shail**
Cultivation technology without tillage (no-tillage) or minimum Soil Cultivation (OTM) is a conservation tillage technology developed in the 1980s. However, this technology is not new in Maluku because, since time immemorial, our ancestors have used simple tools such as suang. (Maluku Tengah) and Shail (MTB) as a substitute for a hoe for limited tillage. This technology is very suitable for Maluku because the soil’s topography tends to be sloping, so it is susceptible to erosion. In perfect soil cultivation (OTS), the soil becomes looser and lighter so that it is not resistant to beating raindrops. On the contrary, with TOT or OTM, the soil is heavier and resistant to beating raindrops.

3.9. **Alley Cultivation Technology**
Alley cultivation technology is a practical approach in conserving soil fertility. Perennials are planted in rows at a distance, which creates space between the rows for planting short-lived perennials and biennials to allow space between perennial plants' rows. It is advisable to plant the perennial rows in an east-west direction so that the row plants' shadow does not cover the intercrops. The selection of perennial plants and perennials in alley cultivation should pay attention to mutually beneficial interactions (symbiotic mutualism) or at least one that benefits the other without experiencing a loss at all (commensalism). For example, plants such as gamal, lamtoro, calliandra, or sengon planted in rows can fix nitrogen and serve as a green manure source for food crops. Likewise, on the other hand, for example, annual plants and biennial green manure are planted between rows of perennial plants instead of green manure.

3.10. **Wise weed control with critical period calculations**
If we look at the time a farmer takes in gardening, we can conclude that most of the time is spent pulling weeds or clearing grass from their plants. Until now, the habit of our farmers is to control weeds or weeds (grass) from their crops at any time even though they have not yet crossed the economic threshold [17]. They do not want any grass on their crops, especially food crops. This is what takes up their time, even though weed control should pay attention to the crop's critical period. The critical crop period is the period in which the presence of weeds must be eliminated, so weed control only occasionally, not all the time [18]. Control at any time can cause losses in the form of time required a lot, and if the grass is often cleaned, the soil is more easily eroded. One of the benefits of weeds is to resist erosion [19]; [20].

3.11. **Jug Irrigation**
The jug irrigation system has actually been practiced for a long time in several places in Indonesia, estimated since 1996. The jug irrigation system is more efficient because the plants' water is all absorbed by the plants, and none is wasted. This system is implemented simply by immersing a jug filled with water in the ground. The jugs used are made of clay and other materials so that the water in the jugs can seep into the plant roots. The planted jug is filled with water through a hose connected to the water barrel. The water in it will seep into the surrounding soil through its permeable walls. The ability of the jug walls to infiltrate water is designed in such a way as to compensate for the evapotranspiration needs of the plant at any time and with due regard to the hydraulic properties of the soil. Filling water into the jug can be done in two ways, namely manually and automatically. The manual method can be done if the number of jugs is limited or there is sufficient labor. Meanwhile, the automatic method is to apply the principle of the connected vessel. Namely, on the one hand, it is a jug
and on the other is the water source tank. The jug irrigation system can be used to cultivate seasonal and annual crops and young perennial crops. This method is one of the techniques in water-saving irrigation on dry land [21].

3.12. Drip Irrigation

Drip irrigation provides water with low discharge and high frequency in a sustainable manner to crops either through the soil surface or directly to the root zone using either a single emitter or in the form of a drip line (perforated hose). Water flow in drip irrigation utilizes capillary and gravitational forces that move vertically and horizontally in the soil profile. Drip irrigation has an efficiency value of 80-95 percent compared to bulk irrigation and surface irrigation. Provision of water in small and sustainable volumes through drip irrigation aims to maintain soil moisture and avoid water loss through percolation and runoff processes so that water availability for crops is still fulfilled. Drip irrigation technology can manage water provision in the root zone of crops in a sustainable manner to increase land productivity, and cultivation activities can last all the time. The application of a drip irrigation system based on an automatic control system can increase the efficiency of water use in crops because it can work based on the actual conditions of agricultural land through soil moisture levels. This is very suitable for dryland agriculture, which is generally water-limited [22].

3.13. Implementing Sustainable Agriculture

The vision of agriculture in the future is sustainable agriculture, which aims to increase farmers' productivity and welfare while preserving environmental resources. Sustainable agricultural systems rely on the empowerment of local agricultural resources, both physical and human resources, supported by site-specific sustainable technology managed by agribusiness [23]. The concept of sustainable agriculture itself is derived from the basic concept of sustainable development. Namely, the needs of human life today can be met without sacrificing the ability to meet the needs of the next generation. The boundaries of sustainable agriculture themselves are very diverse. However, the common thread that becomes the basis is that (1) agriculture must be more productive and efficient, (2) biological processes in situ must play a more important role, and (3) internal nutrient recycling is prioritized [24]. The definition of sustainability contains the meaning of income sustainability (agribusiness perspective) and natural resource sustainability (environmentally sound). In simple terms, these limits can be formulated as follows:

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\text{Sustainability} = \text{Production (Income)} + \text{Resource}
\]

Sustainable agriculture is the successful management of agricultural enterprises' resources to change human needs while maintaining or improving environmental quality and conserving natural resources [25]. By defining and assessing more broadly, agriculture can be said to be sustainable agriculture if it includes the following characteristics:

a) Ecologically stable, which means that the quality of natural resources is maintained and the agroecosystem's overall capacity from humans, plants, and animals to soil organisms is enhanced. Local resources are used so that the loss of nutrients, biomass, and energy can be reduced as low as possible and can prevent pollution. The emphasis is on using renewable resources.

b) Can be economically sustainable, which means that farmers can produce enough to meet their own needs and/or income and get sufficient income to return the energy and costs incurred. This economic sustainability can be measured in terms of ongoing agricultural products and other functions such as conserving natural resources and minimizing risks.

c) Fair, which means that resources and power are distributed so that all community members' basic needs are met, and their rights in land use, adequate capital, technical assistance, and marketing opportunities are guaranteed. All people who have the opportunity to participate in decision making, both on the ground and in the community.
Humane, which means that all life forms (plants, animals, and humans) are respected. The basic dignity of all living things is respected, and relationships and institutions incorporate fundamental human values, such as trust in honesty, dignity, cooperation, and compassion.

e) Flexible, which means that rural communities can adapt to ongoing changes in farming conditions, such as population growth, government policies, market demand, and so on. This includes not only the development of new and appropriate technology but also innovation in a social and cultural sense.

In agricultural development, increasing production is often given the main attention. However, there is a maximum limit to ecosystem productivity. If this limit is exceeded, the ecosystem will be degraded and likely to collapse so that few people can survive with the remaining resources. Production and consumption must be balanced at an ecologically sustainable level. Although sustainability is viewed from a dynamic concept that allows the changing needs of an ever-increasing global population, basic ecological principles oblige us to realize that agricultural productivity has limited capabilities. According to FAO, environmental problems in developing countries are largely due to over-exploitation of lands, expansion of planting, and deforestation [26]. Several large irrigated areas have been damaged by sanitation. In particular, the degradation of soil fertility and the scarcity of wood fuel show concern about this problem.

3.14. Use of Drought Resistant Varieties
One of the government's efforts through the Food Crops Research and Development Center (Puslitbangtan) in overcoming water shortages in the dry season or the impact of extreme climate change is by researching to obtain drought-resistant crop varieties. Many varieties that have been successfully developed include: (a) lowland rice, such as Inpari 18, Inpari 19, and Inpari 20; (b) apart from lowland rice, there is also upland rice, such as Inpago 4, Inpago 5, Inpago 6, and Inpago 8; (c) droughts tolerant maize Bima 4 for hybrid types and Lamuru for composite types. Apart from lowland rice, upland maize, and maize, various varieties of mungbean, peanut, and soybean have also been found to grow on dry land.

3.15. Determination of the Right Planting Time
Climate change has various impacts on life on earth, including farming techniques. In agriculture, climate change, among others, causes a shift in the planting season so that various anticipatory measures need to be made. The Center for Research and Development of Agricultural Land Resources (Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian) has produced a planting calendar map useful in planning cropping patterns according to climatic conditions in each area. Determination of planting time is closely related to groundwater availability for agriculture, which is a cultivation technique by utilizing water stored at the soil surface for plant needs. This technique is beneficial for areas that have low rainfall levels or have climate types D to F (Q value 0.6 to 3) based on the Schmidt-Ferguson climate classification [27].

3.16. Utilization of Embung (water reservoir)
In principle, agriculture is synonymous with water and sunlight harvesting; these two elements are essential in the photosynthesis process as a sophisticated factory producing various agricultural products. Limited water can reduce yield to a total crop failure (puso). Embung is a pond or reservoir for collecting and storing rainwater during the rainy season, and the collected water can be used as irrigation during the dry season. Thus, rainwater can be harvested during the rainy season to store it temporarily and use it in the dry season [28]. Such is the importance of reservoirs for people with minimal water that the government, through the Ministry of Agriculture and the Ministry of Health, annually builds reservoirs in villages in small islands that have limited groundwater availability.

3.17. Utilization of Mulches
Mulches are ground cover materials, both organic and inorganic (plastic). The use of mulch is useful for maintaining soil moisture, reducing evapotranspiration, suppressing weed development, reducing
fertilizer loss due to evaporation, suppressing the development of plant pest organisms, increasing sunlight intensity, avoiding fertilizer loss, saving pest control costs, reducing surface runoff. Moreover, it finally increased yield [29].

In a study with shallot, the application of cow manure at ca. 30 tons per hectare significantly affected the growth and yield of bulbs per hectare, which increased both with or without mulching. The rice straw mulch effect was more dominant than the effect of cow manure on tuber dry weight per hectare [30]. Straw mulch and silver, black plastic mulch resulted in increased leaf area, plant dry weight, tuber number, and tuber weight per crop. However, there was no difference between the mulch treatments in a study with potato [31].

3.18. Government Policies that Support Dry Land
Most of Indonesia's agricultural lands have a hilly topography and have increasingly smaller flat lands available for agriculture. The consequence of utilizing a hilly land is that it is difficult to irrigate since it tends to dry out. Most of the farmers who are outside Java Island cultivate their land with various crops in intercropping patterns. It is hoped that the central government policy will not leave its support dry land because dry land is identical to the local food supply. Abandoning dry land is synonymous with abandoning local food supply. It is necessary to remember that a weak local food supply will lead to weak national food security. Therefore, it is suggested not only to build rice field irrigation but also build dry land irrigation.

4. Conclusion
The conclusion obtained from this paper's discussion is that dryland can make a major contribution to the achievement of Indonesia's food independence through the application of dryland technology. Communities that inhabit small islands can survive by sustainably managing local natural resources by applying upland technology wisely that has proven beneficial for people on small islands. It is suggested that the central and regional governments need to continue to pay attention to the food needs of small island communities with a policy that supports good utilization of drylands so that there is no impression of food shortages on an island.

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