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Indigenous Knowledge of Peanut Cultivation of the Ethnic Khmer Resident in the Mountainous Area in An Giang Province, Vietnam

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***Abstract*—Indigenous knowledge (IK) can provide useful information on local people's activities within environmental contexts. For countries vulnerable to climate change as Vietnam, research on IK might assist in revealing information about local people's responses to environmental stresses and potentially support decision-making. To enrich the study context in this field, this study aims at determining the IK of peanut cultivation of the Khmer ethnic groups. The study site is in the mountainous area in An Giang province, Vietnam, where the Khmer people are located. The methods of documentary collection, focus group discussion, semi-structured interviews, and experiments were applied in this study. The investigation results showed the innovation of local people in the cultivation. For instance, applying cow manure to a sandy soil can reduce chemical fertilizers and improve peanut yield. The IK reported that the application of the broadcasting method could achieve the cultivation economic profit approximately 2.5 times higher than the dibbling method. The former method is mostly preferred due to its time/labor saving and the growing aged population in the study location. The experimental results indicated that the combination of indigenous and scientific knowledge in peanut cultivation, such as chemical fertilizer application, crop calendar, crop rotation, and varieties, could bring high economic efficiency, improve soil nutrients, and ability to adapt to climate change. The research approaches in this study comprehensively revealed the IK, which can be potentially applicable to similar studies.**

***Keywords*— Indigenous knowledge; ethnic Khmer; peanut cultivation; climate change; cow dung.**

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I. INTRODUCTION

Vietnam has fifty-four ethnic groups, some of which have lived for years in the country's southern region and have their cultural traditions and unique agricultural practices. Their activities mainly rely on their experience, traditional practices, and knowledge drawn from environmental observations [1]. However, the accrued local knowledge of the indigenous groups is being lost rapidly. With a population of 1,319,652 people [2], the Khmer group ranks sixth in size among all groups in the country. They reside largely in the VMD, including Vinh Long, Tra Vinh, Can Tho, Soc Trang, Bac Lieu, Ca Mau, Kien Giang, and An Giang provinces [2]. They like to live in the high land, such as sand dunes and mountains lacking water in the dry season, and have developed their own indigenous knowledge in agriculture to adapt to extreme weather.

Climate change is one of the biggest threats to humanity, with its increasing magnitude on a global scale. It extensively impacts the VMD region [3]. Currently, the VMD is facing challenges in its history of formation and development. The sea level rise is the first challenge, with an increase of 3.6 mm per year [4]. The second challenge is water scarcity in the dry season [4]. The third challenge is drought due to the upstream hydropower dams reducing water flown to the lower Mekong Delta River [5].

In the VMD, agriculture is the main activity and a sensitive sector to the challenges, one of the regions most affected by natural hazards [6]–[8] and depends on water use in the Upper Mekong River Basin [9]. Part of the VMD, An Giang (AG) province is situated in upstream and is one of the largest riceproducing provinces in Vietnam. Over the last decade, water flow and quality downstream have reduced due to the appearance of more than 140 large hydropower dams, some of which were in the mainstream of the Mekong River [4]. Consequently, water shortage for agriculture in the two mountainous districts of Tinh Bien (TB) and Tri Ton (TT) of the AG province has become more serious in the dry season. The water shortage has directly affected all aspects of people's lives in this area, especially the Khmer group. Because they mostly live along the mountain-foot plain, cultivating crops and raising cows are their main sources of livelihood. The Khmer population accounts for 25% of the total population in the TB district [10] and 34,02% of the total population in the TT district [11]. Due to the lack of natural rivers in this area, the government has constructed canals, upper canal systems, and additional pumping stations to supply the water from the Bassac River (a branch of the Mekong River) used in agriculture and domestic. Furthermore, the land surface in these districts is tilted from the mountain to flat land, where many arable lands are not supplied with irrigation water in the dry season.

In the past, traditional rice rotation farming systems with vegetables such as peanuts, mung bean, corn, and cassava adapted well to the water shortage. The Khmer people also use cow dung as organic fertilizers to supply nutrients to crops, which formed the local knowledge of adaptation to water scarcity for crops. However, the high population and food security pressure have changed this cropping system to intensive rice (high-yielding rice varieties - HYV). In reverse, some farmers continue to maintain cultivate peanuts. Previous studies have indicated the high tolerance of peanut plants to drought. The peanut plants could adapt to low watering depending on the growing stages, especially at the seedling stage, which does not require much water [12].

Moreover, cow dung is fertilized in peanut fields to improve soil fertility and increase crop yield. Some small groups of native Khmer people still cultivate peanuts in combination with HYV and continue to use their experiences to adapt to the lack of water in the mountainous areas where water is difficult to supply. Such a situation promotes the Khmer farmers to combine IK from previous generations with scientific knowledge in practices in climate change adaptation. The IK should be recognized and shared in communities; however, this has not been well reported. For this reason, our research was carried out to investigate IK of the Khmer in peanut cultivation and then conducted analyses through experiments.

II. Materials and Method

A. The Selecting the Study Site

The TB is a mountainous district with a large Khmer population concentrating in several communes such as An Hao, Van Giao, Vinh Trung, and An Cu (AC). The AC commune has a plain terrain inclined at the mountain foot, as in Fig. 1(a). In 2021, the AC commune had a natural area of 4,224.2 ha with 9,164 people, of which Khmer people accounted for 73.64% of the population.

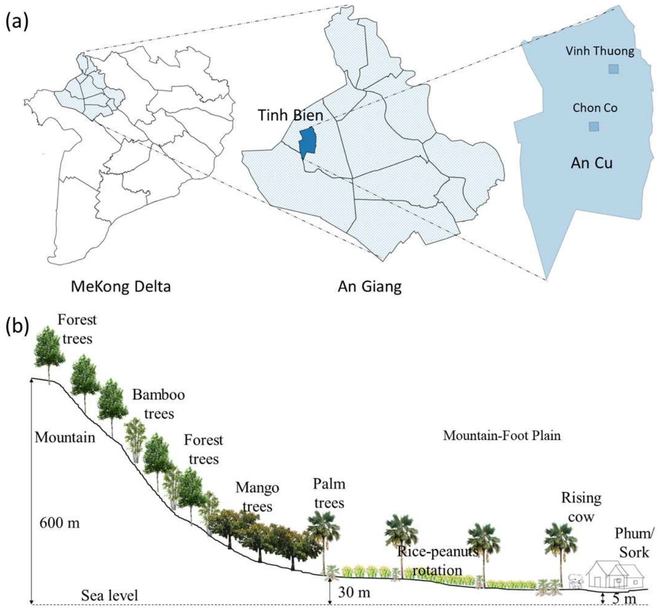

Fig. 1 (a) The map of the study area; 1(b) The transect of the cropping system in the AC commune

Regarding terrain, the AC commune is located in an area with an elevation of 5 to 30 meters above sea level and gradual tilting, so drought frequently happens yearly during the dry season (Fig. 1(b)). The Khmer's culture in the AC commune represents the culture in the mountainous zone. The livelihoods of the Khmer are based on the agriculture and livestock sectors. They often settle in concentrated areas far from the highway or reside beside the "srok" and "phum" mounds. Accordingly, phum is the smallest social organization (micro), and many phums form srok, the Khmer's most complete unit. The phum of the Khmer is the residence unit of one or more families, but it is also a traditional Khmer social institution. Due to the low level of education and ability to listen and speak Vietnamese, the Khmer's capability to receive and apply scientific knowledge to production is slower than that of the other ethnic minorities [1]. In addition, their livelihood is mainly based on farming and raising livestock; thus, they are usually needy, insecure, or unemployed, and have low incomes. They also lack experience, production skills, and management knowledge, resulting in low production efficiency [10]. In 2021, in the AC commune, there are 7.16% of poor households. If the number of near-poor households is included, this proportion will increase to 10.9%. These impoverished households are Khmer [13].

B. Data Collection

The research was implemented in the TB district from January to July 2021. This study applied a combination of qualitative, quantitative, and experimental methods of IK in peanut cultivation. Data collection methods include secondary data, key informant panels (KIP), semi-structured interviews, Focus Group Discussions (FGD), and experimental observation (see Fig. 2).

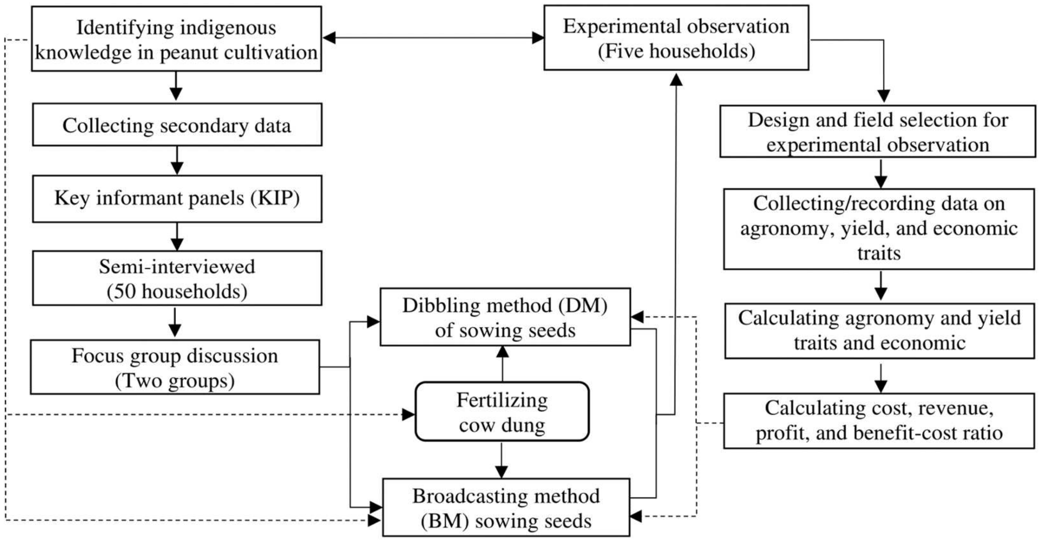

Fig. 2 The research design for data collection

We have collected and reviewed relevant documents on geographical features, natural conditions, and the history of peanut cultivation in the TB district from 2000 to 2019. The authorities and staff from the Agricultural Department of the TB district, the AC commune, and the hamlets' head were interviewed for KIP. The content of the interview is related to population, number of poor households, characteristics, and the history of peanut cultivation. The semi-structured interview was conducted with fifty farmers in the AC and An Hao communes. The content of the interviews focused on the application of IK the people in daily life and farming activities, costs, revenue, and profit from peanut cultivation. Then, two FGDs were conducted in these hamlets, with 7 to 10 farmers aged 30 to 60, both male and female, peanut cultivation in each group. In the FGDs, we used three tools to collect information: historical research, a crop calendar, and a Venn diagram.

- Historical research tool is the discovery of records and narratives of past events [14]. This method allows describing important and interesting past events related to the peanut farming practices of the Khmer by listing or drawing the events in a chronological sequence, then embedded in the narrative analysis;
- The crop calendar tool was used to identify IK applied by the Khmer in peanut cultivation to contribute to reducing yield losses. This tool helps identify IK that has been applied the soil preparation, fertilizing, the appearance of diseases and pests, drought tolerance, and the destruction of crops by rats; as well as evaluate the effectiveness and sustainability of peanut plants to adapt to drought;
- Venn diagram assists in quickly identifying activities of various cooperative groups, traders, plowing services, etc., and organizations such as hamlet committees, pagoda, bank, etc. in the community and evaluate their relationships with the communities.

Five farmers applying their IK to their farming production have been selected for experimental observation based on the research stages.

C. Experimental Observation and Data Analysis

To verify the practical value of IK in peanut cultivation, this study has examined the effectiveness of two sowing methods, including dibbling and broadcasting, as well as cow manure fertilizer. The dibbling method (DM) is the form of sowing seeds on the land band in rows with a certain distance, 2-3 seeds per hole. The distance of the holes is 20-25 cm and one of the rows are 25-30 cm apart. While the broadcasting method (BM) is understood as the form of dry seeds being spread on plowed land, then digging upper lips. Five householders in the Vinh Thuong hamlet, two households applying the BM and the rest applying DM, participating in the experimental observation were selected based on their livelihood assets, including labor, land and water resources, means of production, product transportation, financial capital, and social relations. Furthermore, farmer collaboration in the farming process, such as recording information related to varieties, volume of pesticides and fertilizers, and gross costs, must be considered.

At harvest, the gross cost, revenue, profit, benefit-cost ratio (BCR), as well as capital efficiency ratio have been analyzed for each household. The gross cost of the crop is all the costs that farmers spend in the production process, including the cost of tilling, seeding, buying lime, fertilizers, pesticides, hired labor, and other costs such as irrigation water, clear plastic, mouse traps, etc. The profit is calculated per hectare from the revenue and cost. BCR is the ratio between profit and costs for comparison.

For the agronomic of peanuts, the height and the number of branches.plant^{-1} were randomly determined by three peanut plants in each frame at 15, 35, and 65 days after sowing (DAS) and harvesting. Five frames were collected for each field experiment, and the dimensions were 0.5m × 1m. The height of peanuts was measured from the ground to the top of the highest leaf, and the number of branches growing from the main trunk per peanut was counted. After harvest, all peanut pods in five frames were collected, cleaned, dried, seeded, and weighed. The dry weight is converted to tons.ha^{-1} at 10% moisture.

The peanut yield is calculated from formula (1) to formula (6) and multiplied the ratio by formula (7), where the number of upper lips (a) and number of grooves or lower lips (b) are calculated according to the formula (1) (2) and (3) as follows:

$$aS_x + bS_y = 1000m^2 \quad (1)$$
$$b = a - 1$$

Where, S_x is the area of the land band; S_y is the groove area between two upper lips.

$$S_x = 1.2m \times 25m = 30m^2 \quad (2)$$

$$S_y = 0.35m \times 25m = 8.75m^2 \quad (3)$$

From that a = 25 and b = 24.

Area *(S_{AC})* and yield of peanuts *(Y_{AC})* are calculated as follows:

$$S_{AC} = 1000 - \sum S_y = 1000 - (8.75 \times 24) = 790m^2 \quad (4)$$

$$Y_{AC}(kg/1000m^2) = \frac{\sum_{i=1}^{5} M_{G(i)}}{5 \times S_o} \times 2 \times 790 \quad (5)$$

Where, M_G: the fresh weight of peanut; i = 1, 2, 3, 4 and 5 corresponding to the fresh weight of peanut in each frame; S_o: the area of the frame is 0,5 m^2; The number of frames is five.

The moisture content of dried peanuts is calculated as a formula:

$$W_{10\%} = \frac{(100 - H) \times W_H}{90} \quad (6)$$

Where $W_{10\%}$: the weight of dried peanuts at 10% moisture (g); W_H: the weight of peanuts at H% moisture (g); H: peanut moisture is measured by the seed moisture meter of Kett.

The peanuts were weighed after drying; then, the seed was extracted and weighed. The percentage of seeds was determined using the following formula:

$$\%S = \frac{M_S}{M_F} \times 100 \quad (7)$$

Where %S: the percentage of seeds; M_S: the weight of seeds (gr); M_F: the weight of peanuts (gr).

III. Results and Discussion

A. IK in peanut Cultivation of the Khmer

1) History of peanut cultivation: Results indicate that peanuts have been cultivated since 1960 in the AC commune. Initially, from 10 to 20 Khmer farmers cultivated only the summer-autumn crop. They used rainwater for irrigation. At the start of the rainy season in April, seeds are planted, and local peanut varieties such as 'Mo Ket' are used every year. In 2000, many households switched to tobacco. Simultaneously, the pumping station for upper irrigation with the name '3/2' was constructed and completed in 2004 to provide water for the mountain-foot plain of the TB district. From June 2006, the tobacco growing area was changed to cultivate watermelon, sweet potato, cassava, mung bean, peanuts, and other crops. Therefore, the peanut cultivation area in the TB district has increased by 46 ha from 2000 to 2006 with more new peanut varieties such as DP25 and HL25. From 2007 to 2019, the area of peanut cultivation expanded from 72 ha to 409.8 ha (Fig. 3) because the pumping station was operated to provide irrigation water to the highland in the AC commune. Peanut production plummeted by up to 50% in the winter-spring crop of 2018-2019 as temperatures rose and a slew of diseases and pests attacked. The average peanut yield in 2019 of the TB district (2.62 tons.ha^{-1}) is equal to 0.63 times in 2018 (4.17 tons.ha^{-1}) [15].

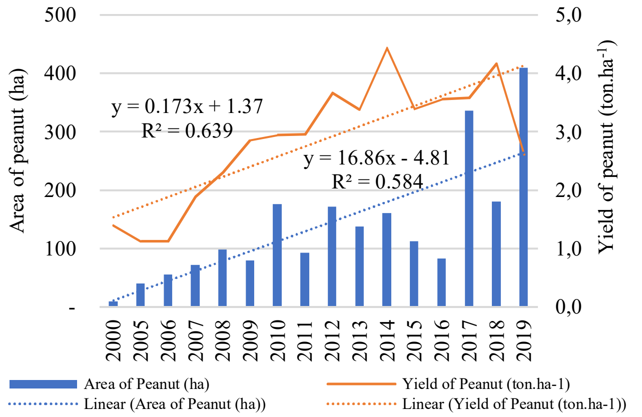

Fig. 3 Area and yield of peanuts in the TB district from 2000 to 2019

In 2020, due to the impact of the Covid-19 pandemic, it was difficult to export peanuts to Cambodia. For this reason, the traders purchased in small quantities, mainly for domestic consumption. At the same time, rice prices rose owing to enhanced import demand from countries worldwide. Since rice would be easier to sell and yield a higher profit than peanut products, many households switched to rice cultivation. Therefore, the peanut cultivation area was reduced in 2020.

2) Factors affecting the peanut yield: According to the results of the FGDs, ten factors that have affected peanut yield are ranked in descending order. The first one is water scarcity. Peanuts are suitable for cultivation in the dry season, like the winter-spring crop. However, the lack of water will strongly impact the yield, particularly during the beginning bloom stage (25-30 DAS), causing a high seedless ratio (about 60%).

The second factor is the presence of diseases, pests, and rat infestation. Many diseases often occur around May because the seasons change from dry to wet during this year, and it is quite convenient for the appearance of yellow leaves and leaf spot diseases. In addition, leaf worms, white worms, and weeds have also negatively affected peanut yield. However, the farmers also have more experience treating them with pesticides. They also have participated in training on peanut cultivation techniques from the TB district's Department of Agriculture and Rural Development, and they also have regularly exchanged experiences with other households in the community. Rat infestation affects peanut yield after the beginning bloom stage. To minimize the infestation of rats, farmers often use transparent plastic around the field and mouse traps.

The third factor is 'visiting the field often'. Peanut cultivation requires farmers to observe fields a lot by 'visiting the field often'. Farmers need to visit the fields, from germination to full pod stages. From three to five DAS, the peanut field needs to be well aerated in soil, with enough humidity for seed germination and enough nutrients to develop the nodule stage at 15 DAS. This stage necessitates additional operations like lightly plowing the soil to help root system development, establishment of nodule perfected, and weed management. 'Visiting the field often' can also accurately assess pest symptoms and make quick decisions on how to handle pests (rats) or diseases (rust spots, black or brown spots on leaves) on peanut fields.

The fourth factor is to use cow manure as organic fertilizer. The sandy soil has low nutrient content to support plants, so it needs more organic matter to hold other nutrients. The farmers remarked, "The cow manure may aid us in saving money on buying chemical fertilizers". They also said, "When we used cow manure at the winter-spring crop, we did not need to use fertilizers for the next summer-autumn crop". "If the rice is cultivated in the next crop, it grows very well and gives a relatively higher yield than the field that uses completely chemical fertilizers". Cow manure contains 24 minerals, such as nitrogen and potassium, and additional trace amounts of sulfur, iron, magnesium, copper, cobalt, and manganese [16], [17]. Cow manure contributes to an increase in the organic matter content of the soil, leading to improved water retention in the sandy soil, helps resistance to drought, and increases cation exchange capacity that mobilizes nutrients to provide plants [18]. Besides, cow manure also contributes to increasing soil fertility and the availability of phosphorus [19]. However, cow dung leads to many weeds growing in the field, which needs more labor to uproot them. Additionally, cow manure must be processed through many stages, requiring many laborers.

The fifth factor is chemical fertilizers. They have an instant effect on plants and a wide range of essential fertilizers, making it easy for farmers to choose. The use of chemical fertilizers is very convenient but costly and lacks the intermediate substances that cow manure contains, such as Ca, Mg, K, etc., which are critical minerals for plants.

The sixth factor is the planting method. Khmer farmers in the AC commune use two planting methods, DM and BM. Despite being trained in the DM, many of them believe that the BM has more advantages. They said, "The cost of the BM is 70% less than that of the DM, and peanut can be harvested simultaneously". They also said, "There were still many disadvantages such as the high amount of varieties, many weeds in the field leading to high weeding cost". Especially because peanut plants grow very thick and the plant's height is tall with little tillering, making pegging difficult and yield low. In addition, the BM cannot be used in low-lying fields because water will flow from high to low land, preventing seed germination.

The seventh factor is the peanut variety which mainly contributes to the yielding. However, due to the rapid loss of germination, only a few farmers can store the seed for the next crop. They usually switch fields; for example, peanuts have been grown in lowland fields during the dry season and in upland areas during the wet season. Normally, in the autumn-winter crop, they do not cultivate peanuts because of the heavy rain, so they often cultivate rice in this crop instead. A solution often applied by the farmers is to borrow seeds from relatives or neighbors and return the borrowed seeds in the next crop. If there is a lack of seed, the farmers must buy the seed at a high price, ranging from 2.2 - 4.3 times higher than the price of peanut products.

The eighth and ninth factors are that the rainfall and sandy soil have a negligible effect on the yield. If the farmers have determined to cultivate peanuts in the lowland, it will be flooded due to the surface irrigation from high to low areas. Thus, they often choose the upland and cultivate peanuts on the upper lips. When it rains heavily, the water drains quickly. The beginning bloom stage needs more water and drains quickly so the pegs can easily extend into the sandy soil and begin pods. The soil moisture must reach 70% to help the peanut grow more branches and flowers. The farmers said, "In the beginning bloom stage, if the rain occurs only two times, it will help the peanut grow and develop well".

The tenth factor is the cultivation experience. However, the farmers are not interested in the experience of peanut cultivation because they have 10 to 16 years of experience. In their opinion, the technique of peanut cultivation is relatively easier than other vegetable cultivations such as watermelon, mung bean, etc.

3) Applying IK in peanut cultivation: The majority of Khmer families keep cows. They are traditional Khmer livestock in rural areas. The barn of cows is usually located right behind or next to their house because cows are animals with traction and help farmers to plow and pull the crops. So they are nurtured well and taken care. Previously, when the tractor was not developed in poor rural areas, people used cows to carry agricultural products and materials. Nowadays, cows are only used for plowing fields. Some couples of cows can plow and harrow in the same field, and then move to the next one. This form is called 'rhyme exchange'. When the harvest comes, cows are used to transport agricultural products and straw from the field to the house. Cow manure is very beneficial and is used as organic fertilizer for cultivating sandy soil. The lifestyle of Khmer people in rural areas cannot lack cow raising because cows can help more sustainable agriculture production in the sandy soil areas with drought. For this reason, cow farming is passed from generation to generation.

The cow manure is slowly stored in the cellars next to the house for natural decomposition without the composting stage. At the beginning of the winter-spring crop, it is transported to the field for drying. Before fertilizing the cow manure, the soil must be plowed and dried in 5 to 10 days and then plowed the second time. The farmers will use cow manure, chemical fertilizers, and lime to increase soil pH. According to the farmers' experience, cow manure is usually used once a year in the dry season because soil microbes have not entirely decomposed it in the wet season.

Furthermore, the combination of soil and cow manure promotes the rapid growth of earthworms and white grubs. The percentage of pods that have a dark color will increase. Earthworms play a role in improving the soil environment by decomposing organic residues and converting them into humus and minerals. Earthworm manure is rich in nutrients with components such as N, P, K, Ca, Mg [20], and it also helps to loosen the soil. White grub is the larval form of the beetles, which are usually laid in the cow dung, then develop until they pupate or live on the nearby ground [21]. In the form of white grub larvae, they often eat newly forming roots and leaves, causing the yellowing of leaves [22].

In addition, throughout many years of peanut cultivation, Khmer farmers have realized the effectiveness of the two sowing methods. The BM has been applied for a long time and has been transmitted to subsequent generations. As a result, it is classified as IK, whereas DM is considered scientific knowledge. Farmers who were trained in the DM three years ago have used this strategy. The outcomes of the

FGDs reveal a comparison of the DM and BM utilized by the farmers in the community. The first is that the DM has more advantages over the BM in terms of land application, seed and weeding costs, and a better full pod rate and yield. Next, while the plant height of DM is shorter, it is beneficial for beginning peg and pod. Besides its high cost, lack of labor, and time-consuming process, the main advantage of the BM over the DM is the lower cost of land preparation, a major expense that farmers consider when deciding on a peanut crop. Last, farmers indicated that in some peanut fields, "the yield from both approaches can be similar". Consequently, these methods are used in tandem in the community, and farmers may choose which way to plant based on the type of their land.

Moreover, farmers' experience shows that crop rotation is frequently used in their fields, which is known as "changing land". They assume that continuous cropping of peanuts on the same field will diminish output owing to bacterial and fungal infections collecting in the soil. In the mountain-foot plain, Khmer farmers in the AC commune typically rotate two peanut crops with a rice crop. This is compatible with the findings of the study Li et al. [23] because the bacteria *Ralstonia solanacearum* Smith is found in soil, crop residues, and weeds. Bacteria may easily enter the peanuts via wounds on the roots and stems. After entering the plant, they assault the conduction phloem tissue and travel along vessels, causing the vascular bundle to be damaged and the plant to be unable to transfer water and nutrients, resulting in withering or death. According to Abu-Tahon, Mogazy, and Isaac [24], the fungus *Rhizoctonia solani Kuhn* may persist in plant by-products and soil, causing root rot symptoms.

Furthermore, Khmer farmers forecast the appearance of pests and diseases in the peanut crop. The plant is commonly damaged by leaf spot disease and leafworm between 14 and 30 DAS, which is the leading cause of seedling death. According to research, a leaf spot in peanuts is caused by two fungus of the genus Cercospora. *Cercospora arachidicola* is a fungus that produces brown spot disease mostly on leaves, whereas *Cercospora personata* causes black spot disease on peanut stems and leaves. When plants are infected, the color of their leaves changes to yellow, and they fall, reducing photosynthesis, growth, and yield [25]. White grubs often occur after 60 DAS and infect the root and pod from the beginning pod to full seed stages.

Additionally, Khmer farmers estimate the quantity of irrigation water needed and identifying water scarcity influences plant development. In the AC commune, the primary method of irrigation for peanuts is surface irrigation using an internal watering system. The upland is irrigated first, and then the water is discharged into the lowland. Water is often held in the field for up to 12 hours. The residual water will then be discharged through the internal ditch irrigation system. Farmers have learned that peanuts are drought resilient due to periodic water shortages throughout the dry season. Plants can tolerate drought well from 1 to 15 DAS when the plants have three true leaves compared to other periods. However, if the plant is not supplied with enough water during the beginning bloom stage, and especially after 40 DAS, the proportion of seedless pods can rise to 60%, leading to low yield. This assessment of Khmer farmers is entirely consistent with the findings of Jiang et al. [26].

Fresh biomass from peanut plants has also been used as cattle fodder. Because the winter-spring crop is grown during the dry season, grass will become scarce over time, and the by-product from peanut plants will provide supplemental fodder for cows. Khmer farmers believe that their cows prefer fresh or dried peanut plants to rice straw. This peanut by-product is rather huge and has a high nutritional value. For example, during the summer-autumn crop in 2021, the area of peanut cultivation in the Vinh Thuong hamlet will be around 3.6 hectares, with fresh and dried peanut plant weights of approximately 56 tons and 11.52 tons, respectively. According to Mondal et al. [27], the highest yield of dry peanut haulm is 3.8 $tons.ha^{-1}$. In addition, protein, fat, and fiber ratios in peanut haulm are 13.94%, 5.11%, and 53.65% of the total. Therefore, if farmers take advantage of biomass from peanut plants, they will drastically diminish the need for grass resources during the dry season.

B. Drought Tolerance and Improved Soil Environment of Peanut and Rice

Two factors provided by CARE [28] are assessed for selecting a farming system to adapt to climate chan: droughts, sandy soil, and interactions between farming activities and the environment. Peanut cultivation takes 90 days, the same as rice cultivation, so farmers can rotate these crops, such as "two rice crops and a peanut crop" or "two peanut crops and a rice crop". Peanuts are usually prioritized to be cultivated in the winter-spring or summer-autumn crop because of their drought adaptation and well growth in the sandy soil, whereas rice is cultivated in the autumn-winter or summer-autumn crop due to its high rain tolerance.

In addition, peanut by-products such as stems and nodules from roots are rich in nitrogen nutrients, allowing more microorganisms to survive in sandy soil and reducing the amount of chemical fertilizer necessary for the next rice crop [29]. Whereas HYV rice typically requires more nitrogen fertilizer and pesticide use than peanuts [30]. If the peanut-rice rotation is expanded on a larger scale, some mountain-foot concerns, such as unequal distribution of irrigation water sources throughout the year, discolored soil, employment for poor farmers, and nutrient source and cows, could be solved.

C. Evaluate the Effectiveness of Cow Manure and Sowing Method in Peanut Cultivation

1) Livelihood assets of households: The labor force is evaluated in this study using criteria such as the number of individuals in each household, the number of major laborers, and the education level of laborers. Table 1 shows the livelihood assets of five households participating in the experiment. According to the survey results for selecting participant households, the number of people in a household range from 2 to 8 people, with 2 to 4 people being the main laborers, including the women, but the women frequently participate in simple activities such as seeding, weeding, fertilizing, and recording the costs and price of peanuts.

The arable land of each household is from 1.02 to 3.5 ha, of which the land for peanut crop is from 0.128 to 0.7 ha. Most of the land is cultivated rice. Irrigation water is provided by pumping stations and rainfall. Due to the small number of main laborers in the family and small farm, farmers often do it themselves to save costs and only hire labor during harvest because they need more manual labor at this period.

TABLE I
RESOURCE OF FIVE HOUSEHOLDS PARTICIPATING IN THE EXPERIMENT OF PEANUT CULTIVATION IN THE AC COMMUNE

	Resources	Description/Range
Human labors	Number of household members	2 - 8
	Main labors	2 - 4
Natural	Cultivated land (ha)	1.02 - 3.50
	Peanut land (ha)	0.128 - 0.700
	Irrigation water	Pumping station and rainfall
	Domestic water	Piped water, rainfall, groundwater
Physical/ Facilities	Communication and entertainment appliances	Television, smart phone, and karaoke player
	Agricultural equipment	Tractor, cultivator, water pump and sprayer
	Transportation	Motorcycle, bullock cart
Social	Farmers' union, Women's union, Veteran's union, etc.	Rarely to participate in union activities
Financial	Income sources	Agricultural products, cattle, seasonal labor
	Income (Million VND.year^{-1})	125.10±64.37
	Bank borrowing	Non-borrowed

Most Khmer farmers have a low education level because of problems in the war, customs, and languages. Among the five farmers, three only graduated from primary school, and the others got to the secondary school level. In general, Khmer residents at the study site who were born in the 1970s had difficulty going to school due to the war in Vietnam [31]. The Khmer people born in the 1980s could go to school because there were enough high schools for them. Furthermore, the Khmer children also come to the pagodas to learn the Khmer language, culture, and customs.

The Khmer people today often use social media and multimedia to communicate and receive information about news, technology, weather, and agricultural product prices which is useful for agricultural practices and entertainment after working on the farm. Some farmers have investigated farming equipment such as agrimotor and tractors to serve themselves and provide services to other families. These main assets directly or indirectly affect farming activities, improving quality and productivity [32].

The Khmer people in the AC commune rarely participate in social organizations such as farmers' associations, women's unions, youth unions, and farmer clubs. They often have a close relationship with the pagoda. Because the ethnic Khmer strongly believe in Buddhism, pagodas are the spiritual support [33]. The Khmer people revere the monks who teach the Khmer language and culture and usually organize community activities such as weddings and funerals. Pagodas play as the bridge in the Khmer communities, between religion and life, and between the government and the communities.

Due to the main activities of the Khmer households in the AC commune related to farming, they often contact the staff of the pumping stations, cooperative groups, plowing services, and agrochemical retailers to be provided with irrigation water, seeds, fertilizers, pesticides, and exchange experiences. However, they do not receive much direct support from the Office of Agriculture Department and local banks. As a result, they do not have many opportunities to access scientific knowledge in agriculture compared to the Kinh people. This is the main reason some households have low agricultural productivity and efficiency, according to the consistency of research findings in Tran et al. [34]. Besides, the Khmer farmers have difficulties understanding scientific knowledge in Vietnamese. There are also not many programs on television or radio in Khmer languagewhich is consistent with the study by Nguyen et al. [1].

The main income sources of Khmer people are farming, raising cows, seasonal labor in agriculture, and small retail or others. The average income of each household is 125.104±64.368 million VND.household^{-1}year^{-1} (Table 1). However, it totally depends on the weather and the price of agricultural products and cows. The households do not desire to borrow from the banks or their neighbors because they want to be financially independent, and this indicates that their financial resources are stable and a key factor in improving productivity and increasing income.

In summary, the households applying IK in peanut cultivation have all resource criteria, including human resources, natural resources, physical resources, society, and financial capital.

2) Agronomic characteristics, the yield of peanuts, and the role of IK: Fig. 4 shows that peanuts have increased in height steadily from 15 DAS to harvest. The average height of peanuts in the BM was 25.5 cm higher than in the DM. Furthermore, Fig. 4 illustrates that the average number of branches-plant^{-1} in the DM is higher than that of the BM. The reason is that the average seed weight in the BM (0.231 tons.ha^{-1}) is 1.31 fold higher than that of the DM (0.177 tons.ha^{-1}). The seeding density can affect the height and the number of main branches. According to Kolekar et al. [35], the low number of branches-plant^{-1} influences yield because peanut flowers are formatted by the axillary leaf in the main term and primary branches.

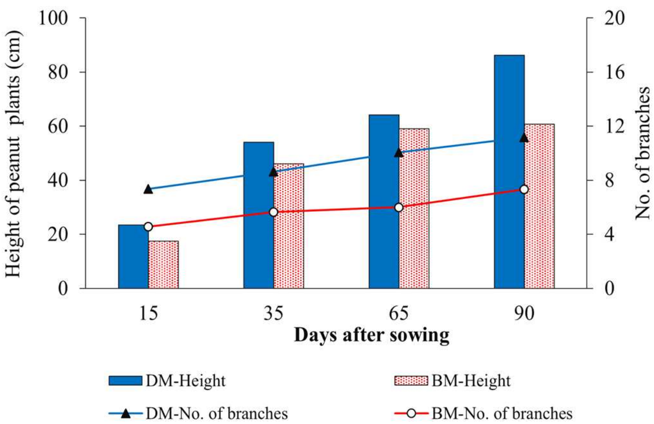

Fig. 4 Average height and average number of branches-plant^{-1} of peanut plants from 15 DAS until harvesting

In the experimental observation, three households (Chau Rum, Chau Chia, and Chau Sin) used cow and bat manure, and the two others used only chemical fertilizers (see Table

2). The recorded data show that Chau Sin, Chau Chia, and Chau Rum used more nitrogen (N) and phosphorus fertilizers (P_2O_5) while Chau Sin used less potassium (K_2O). According to [36], potassium deficiency can reduce the disease resistance of peanut plants. Chau Rum used 6 tons of cow manure, and chemical fertilizers were higher than recommended. The average rates of chemical fertilizers that farmers have applied more are 1.88 (nitrogen), 4.46 (phosphorus), and 0.48 (potassium), respectively, compared to the recommendation for sandy soil in this area [37].

Besides, the farmers did not apply agricultural lime to provide calcium for the peanut crop, making the plant less resistant to diseases and pests. The lime increases soil pH, creating a suitable environment for nitrogen fixation from Rhizobium bacteria at the nodules in the root system of the peanut. It conduces reducing the volume of nitrogen for both peanut and rice next crops [37].

At harvest time (90 DAS), peanut yields at moisture 10% of the households are estimated at 0.253±0.039 tons.ha^{-1} for the DM, and 0.174±0.051 tons.ha^{-1} for the BM. In particular, the peanut yield of Chau Sin is the lowest (0.136±0.029 tons.ha^{-1}), and the one of Chau Rum reached the highest (2.98±0.4 tons.ha^{-1}) (Table 2). Chau Rum and Chau Chia households have the highest yields for two seeding methods, corresponding to the DM and BM. They used cow manure with nearly 6 ton.ha^{1}. Chau Sin's household had the lowest yield because he used bat manure. Cow manure is more efficient than bat manure on peanut yield. Cow manure can produce larger amounts of minerals than bat manure, which is already in the community and low cost.

In general, unbalanced fertilization, lack of calcium, and unused organic fertilizers are the main causes of diseases and pests on peanuts. The experimental observation has recognized some symptoms of black spot disease (*Cercospora personata*), rust disease (*Puccinla Arachidis*), and earworm from the full pod stage to harvest. Fertilizing Cow manure is local knowledge in peanut cultivation, promoting farmers to develop sustainable sandy soil crop systems and water shortage. For the BM, a traditional seeding method needs to be improved with new machines to sow with less seed, combined with more efficient fertilization. The Khmer people usually live together in phum/srok, so they discuss how to apply chemical fertilizers, pesticides, techniques, and peanut varieties together. The FGD results show that when any new technique is demonstrated in the community, Khmer farmers will attend and apply. Farmers use the BM instead of the DM when they don't have enough labor for sowing seeds.

TABLE II

VOLUME OF FERTILIZERS USED AND PEANUT YIELD OF THE EXPERIMENT IN THE AC COMMUNE

Sowing method	Household	Fertilizer								Peanut yield (kg.ha^{-1})	Percentage of peanut kernel
		Manure		Chemical (kg.ha-1)			Formulas (kg.ha^{-1})				
		Cow	Bat	NPK	Urea	DAP	N	P_2O_5	K_2O		
DM	Chau Rum	Yes	-	50.0	-	-	100	100	75	0.298±0.040	69.4±1.20
	Chau On	-	-	34.6	-	-	69.2	69.2	51.9	0.248±0.019	67.9±1.85
	Chau Khao	-	-	35.0	-	-	70	70	52.5	0.212±0.057	63.7±2.25
	Average									0.253±0.039	67.0±1.77
BM	Chau Chia	Yes	-	50.0	-	-	100	100	75	0.212±0.073	63.6±0.518
	Chau Sin	-	Yes	12.5	12.5	25.0	130	107.5	37.5	0.136±0.029	62.6±8.32
	Average									0.174±0.051	63.1±4.42

Note: NPK fertilizer 20-20-15; DAP fertilizer with 18%N, 46%P_2O.

TABLE III

ECONOMIC EFFICIENCY OF PEANUT CULTIVATION BY HOUSEHOLD AND BY SOWNING METHOD OF THE EXPERIMENT IN THE AC COMMUNE

Economic efficiency	Unit	Household		Sowing method	
		Chau Rum	Chau Chia	DM	BM
Gross cost	10^3 VND.ha^{-1}	49,854	46,769	44,501	45,411
Land preparation cost	10^3 VND.ha^{-1}	3,077	3,077	2,780	2,488
Varieties	10^3 VND.ha^{-1}	10,000	10,000	10,037	10,000
Lime	10^3 VND.ha^{-1}	538	538	484	269
Manure/organic fertilizer	10^3 VND.ha^{-1}	3,077	3,077	1,026	3,038
NPK fertilizers	10^3 VND.ha^{-1}	6,700	6,500	5,281	6,350
Pesticides	10^3 VND.ha^{-1}	6,538	4,346	4,727	5,498
Labor	10^3 VND.ha^{-1}	4,962	2,192	5,397	2,462
Harvesting	10^3 VND.ha^{-1}	11,769	13,864	11,577	12,113
Other*	10^3 VND.ha^{-1}	3,192	3,192	3,192	3,192
Average yield (fresh)	tons.ha^{-1}	3.92	4.62	4.22	4.04
Revenue	10^3 VND.ha^{-1}	58,846	69,231	57,885	55,375
Profit	10^3 VND.ha^{-1}	8,992	22,462	13,384	9,964
BCR(%)		18	48	30	21.1

*Note *: Including the cost of irrigation, clear plastic, and mouse traps.*

According to the observation data of two households (Chau Rum and Chau Chia), the number of chemical fertilizers and pesticides is similar. However, the peanut yield's Chau Rum is higher than that of Chau Chia (Table 2). In addition, the gross cost of Chau Rum is higher than that of Chau Chia (Table 3). Consequently, the profit and capital efficiency ratio of Chau Chia is higher than that of Chau Rum. This is a good case study to demonstrate that IK has an important role in peanut crops at the mountain-foot plain of the Khmer resident in supporting farmers to adapt to climate change in the area.

Furthermore, we analyzed and assessed the effectiveness of the two sowing methods based on the average revenue and profit of five households as in Table 3. The result shows that the BM's gross cost is higher than that of the DM mainly because the cost of harvesting and fertilizers is high. Consequently, the DM has more profit than the BM. The major reason is that Chau Sin's household did not provide enough nutrients for the peanuts, such as calcium and potassium, so diseases and pests easily attacked the peanuts, leading to a reduction in peanut yield.

IV. CONCLUSION

The IK of peanut cultivation of the ethnic Khmer in the An Cu commune has been developed over time and focused on dealing with the sandy soil and the water shortage. They have applied cow dung and the broadcasting method to increase yield and save labor. This study figured out that the farmers effectively apply the broadcasting method and are knowledgeable about the benefits and harms of using cow dung and applying the broadcasting method in peanut crops over the years. From a practical point of view, this sowing method is still useful value by the actual situation in the community, which includes a large number of farmers aged 50 years and above.

In addition, the experimental results show that farmers understand how to blend indigenous and scientific knowledge, such as crop rotation, crop calendar, varieties, and chemical fertilizer application, as recommended by the studies for increasing yield and improving adaptive capacity to climate change. This necessitates community agreement and the participation of the Farmers' union, agricultural extension officers, and the leaders of the ethnic Khmer, who are the closest people to the communities.

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