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Farmers' Awareness of Agri-technology Application in the Central Highlands of Vietnam

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Abstract

Understanding farmers awareness of applied agri-technologies is critically important for policy development, training, xtension, and trade. This study was conducted by a survey of 248 households in 89 villages of 20 communes in the Central Highlands of Vietnam. Farm households were aware of technologies including plant varieties, animal varieties, drip irrigation, sprinkle irrigation, handy irrigation, greenhouses, semi-processing, fertilizer, and chemicals, etc. Most farmers utilized simple technologies because of a long-time adoption, but other new or high technologies were poorly understood by the households. Based on the results, a gap has been identified, and recommendations have been given to policymakers, training organizations, extension, and traders regarding household capacity building, and providing new technologies of farming materials and requirements. Furthermore, understanding farmers' perceptions can likely help governance regarding the recent goal of net zero emissions in agriculture and land-use section in Vietnam.

Keywords

Agri-technology, agroforestry, fertilizer, irrigation, pesticide, perception

Introduction

Farmers' awareness of agricultural technologies (agri-technologies) varies based on several traits. Farm households awareness in the Central Highlands of Vietnam differed by ethnic groups that indicated different farmers' awareness (Tran *et al.*, 2025). New technologies are critical to drive agricultural productions towards sustainability and adaptation to global changes, e.g. green technologies (Dong *et al.*, 2023); climate-smart agri-innovative technology adoption and agribusiness management (Khan *et al.*, 2021; Yamoah & Kaba, 2024).

The Central Highlands of Vietnam consist of 4.92 million ha of agricultural land (Central Steering Committee, 2019; Ministry of Natural Resources and Environment, 2019) where agriculture and food

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production have also increasingly become knowledge-intensive (Tran & Tran, 2024). After decades of mono-culture agricultural development with multiple problems, farmers have transitioned more towards agroforestry. However, these farmers have been facing the problem of unsustainable development (Tran & Tran, 2024).

Worldwide, multiple studies have addressed the awareness of farmers (e.g. awareness levels of agricultural production (Vatta & Taneja, 2015); perceptions of farmer use of electronic communication (Aldosari *et al.*, 2019); awareness of fertilizer (Misiko *et al.*, 2011; Yang & Fang, 2015; Nanthini, 2017); pesticide use knowledge and risk awareness of farmers (Yang *et al.*, 2014; Wang *et al.*, 2017); perceptions of climate change and water pressures, water scarcity (Tang *et al.*, 2013; Quiroga *et al.*, 2015; Eitzinger *et al.*, 2018); small-scale farmer innovators and technology (Mottaleb, 2018; Channa *et al.*, 2019; Tambo *et al.*, 2020); awareness of agricultural biodiversity to improve their crop yield (Ali *et al.*, 2020); awareness of Good Agricultural Practices (GAP) (Joshi *et al.*, 2019); organic farming (IOF) (Yanakittkul & Aungvaravong, 2020); food safety policies and practices (Khouryieh *et al.*, 2019); perceptions on rural finance (Kashuliza, 1993; Linh *et al.*, 2019); and sustainable management of indigenous agroforestry systems (Phondani *et al.*, 2020).

Awareness and applying agri-technologies (particularly new and high-leveltechnologies) by farm households (which are limitations of capacity, knowledge, and approach) would be a huge challenge. Therefore, can farmers in Vietnam's Central Highlands be aware of how they respond to those technologies?

Thus, this paper quantified farmers' awareness of agriculture and agroforestry to better understand the real evidence relevant for recommendation and policymaking on sustainable development on both local and regional scales.

Study Sites and Methods

Study location

The Central Highlands have five provinces including Gia Lai, Kon Tum, Dak Lak, Dak Nong, and Lam Dong. The study sites were distributed over the ecosystem zones of the regions, e.g. Ngoc Linh Mountains; Sa Thay lower Mountains; Play Ku and Con Ha Nung Highlands; An Khe lower Mountains; Cheo Reo, Phu Bon, and Ea Sup Semi-plateau; Buon Me Thuat Highland; Man Drak mountains; Dak Nong, Dak Min Highlands; Chu Yang Sin mountains - Da Lat Armenian Highland; and Di Linh, Bao Loc Highlands (Vu Tan Phuong *et al.*, 2012).

Data and research methods

Primary data were collected from direct surveys from 248 households in 89 villages of 20 communes (see more information in the appendixes). The surveys were conducted in 2019. The household samples were selected by snowball sampling method. This approach involves a minimum of two stages: (a) the identification of a sample of respondents with characteristic x at the zero-stage (s_0); and (b) the solicitation of referrals to other potentially eligible respondents believed to have characteristic x at snowball stages s_1 through s_k (Goodman, 1961; Biernacki & Waldorf, 1981; Kirchherr & Charles, 2018).

Data were recorded, classified, and analyzed in Excel program and R program with functions (e.g. describe by; ggplots; and Kruskal Wallis Test). The cultivation systems were divided into five types, including AF1 – agroforestry type including fruit, industrial, and wood trees; AF2 – agroforestry type including fruit and wood trees/ industrial and wood trees; AF-others – other agroforestry types (different with AF1 and AF2); Agr – mono cultivation (only fruit tree or only industrial tree); Agr-multi – multi-cultivation (mixed or intercropped fruits or/and industrial trees); and ethnic groups were divided into three major groups including I – indigenous minority groups; K – Kinh group; Others – other minority groups (immigrant minority people).

Results and Discussion

Awareness of agri-technology application of the farmers in the Central Highlands

Based on the data, the study determined which technologies the interviewed households applied, including varieties of plants and animals, irrigation systems (e.g. drip, sprinkle, and handy irrigation), green-house, semi-processing (e.g. milling, drying, and packing), and others (e.g. ploughing, pesticides, and liquid nutrient). The surveyed households applied technologies of a variety of plants, a variety of animals, drip irrigation, sprinkle irrigation, handy irrigation, green-house, semi-processing, and others were 14.1%, 19.0%, 4.8%, 17.7%, 32.7%, 2.4%, 11.3%, and 33.1% of 248 samples, respectively. Overall, a few households applied technologies in their farms, of which irrigation technologies were likely preferred by 55.2% of the surveyed households, while the rest technologies were less than 33.1% of the surveyed households (**Figure 1a**).

Within five provinces, households mainly applied technologies of plant variety in Lam Dong (13/51 HHs), Dak Lak (13/51 HHs), and Gia Lai (8/48 HHs); sprinkle irrigation in Dak Lak (15/51 HHs) and Dak Nong (10/48 HHs); handy irrigation with electricity or/and petrol engine pumls in Dak Nong (30/48 HHs); Dak Lak (16/51 HHs), and Gia Lai (16/48 HHs); green-houses in Lam Dong (6/51 HHs); semi-processing in Dak Lak (12/51 HHs) and (11/51 HHs) (**Figure 1b**).

By ethnic groups, most of technologies were Kinh's households applied, of which technologies of variety of plants, variety of animals, drip irrigation, sprinkle irrigation, handy irrigation, green-house, semi-processing, and others were 32/187 HHs, 35/187 HHs, 10/187 HHs, 41/187 HHs, 67/187 HHs, 6/187 HHs, 28/187 HHs, and 76/187 HHs, respectively. While indigenous minority households mainly applied technologies of animal variety (11/51 HHs) and handy irrigation (11/53 HHs) (**Figure 1c**).

Analysing by types of cultivation, numbers of technologies which households applied in agricultural systems were different (e.g. average numbers of technologies households applied in AF-others, AF1, AF2, Agr, and Agr-multi were 1.90 (± 0.31), 1.57 (± 0.09), 1.24 (± 0.11), 1.67 (± 0.33), and 2.05 (± 0.15) technologies per household (**Figure 1d**), ($\mathcal{X}^2$ = 15.09; P = 0.0045). However, the numbers of technologies which households of ethnic groups applied were not different (e.g. indigenous minority households applied 1.21 (± 0.10) technologies per household; Kinh households applied 1.81 (± 0.08) technologies per household; immigrant minority households applied 1.00 (± 0.00) technologies per household (**Figure 1d**), ($\mathcal{X}^2$ = 12.75; P = 0.0017).

Surveyed households in the Central Highlands of Vietnam poorly applied technologies in their production systems, especially high-technologies and/or smart technologies. It is likely that farmer's perception of the importance of technology adaptation was limited. Those above technologies applied by the households focus more on yield, but less on improving the added values of their agricultural products. Therefore, many households found it harder and harder to approach the market demands with the old technologies. This discussion could be connected to the awareness of products and markets, and needs to be considered when recommending future changes.

Unfortunately, farmers are not aware of some types of technologies that are very important to approach the new trends for agriculture development (e.g. electronic communication in agriculture (Aldosari *et al.*, 2019), information and communication technology (ICT) in agriculture (Kante *et al.*, 2017; Walter *et al.*, 2017; Trendov *et al.*, 2019), precision agriculture using high technologies (Clercq *et al.*, 2018). Indeed, most farmers cannot identify these new technologies, but researchers, educators, and policymakers need to mention them as soon as possible for future governing programs.

Awareness of the households on varieties, fertilizer, watering, and chemicals in the Central Highlands

Awareness of the households on varieties

The study aimed to determine farmer's perception of varieties utilized in their farms. Generally, being able to identify names and deciding on plants and animals that farmers wanted to produce at their farms could be an "awareness". Based on that, 206 households out of 248 interviewed samples (equivalent to 83.1%) were aware of the different varieties of

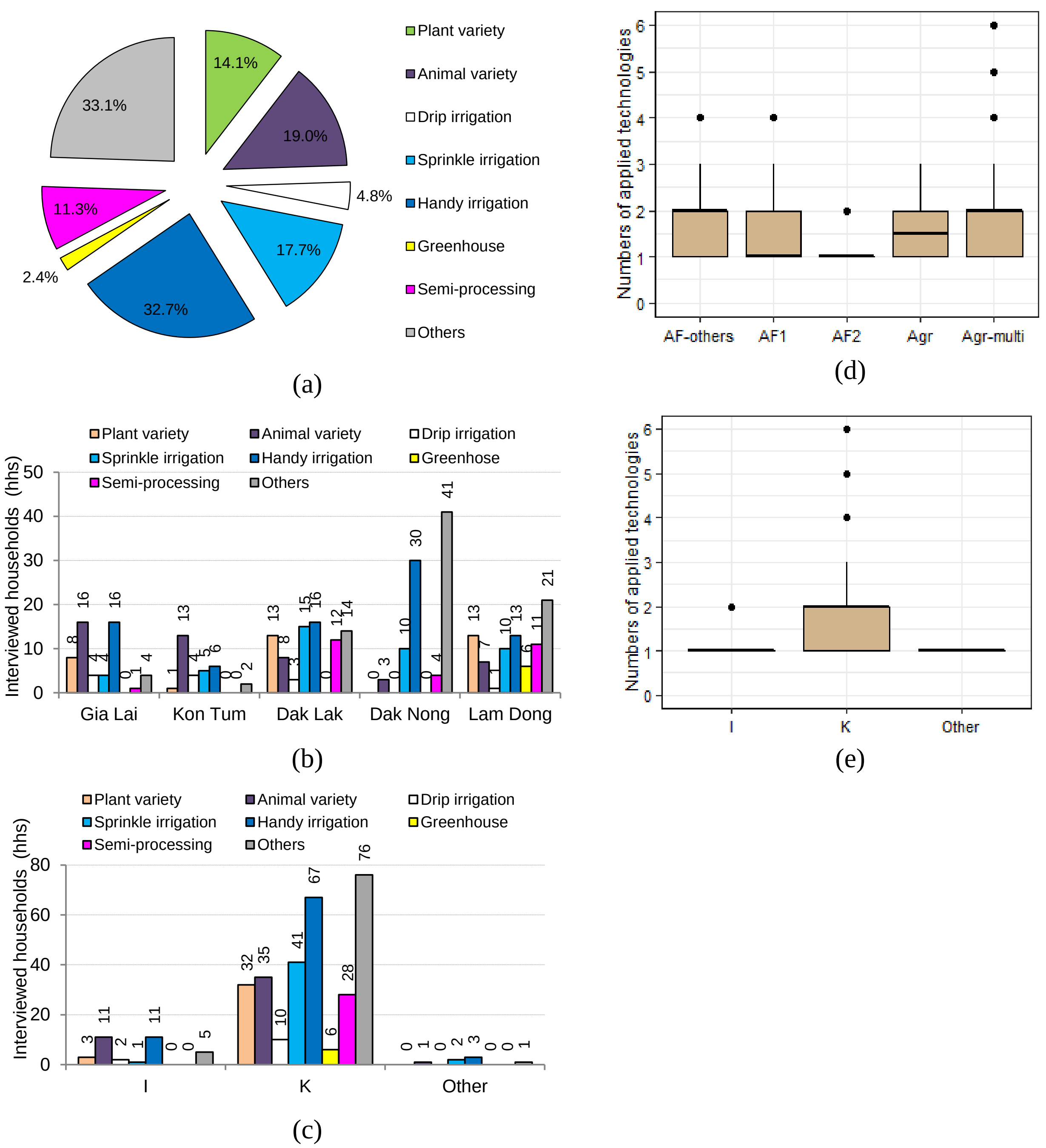


Figure 1. Agri-technology application of households in the study sites (a - percentage of HHs; b - numbers of HHs by provinces; c - numbers of HHs by ethnic groups; d - numbers of technologies per HHs by cultivation types; e - numbers of technologies per HHs by ethnic groups)

plants and animals on their farms. Of these, 73.6% of indigenous minority households (39/53 HHs); 86.6% of Kinh's households (162/187 HHs); and 62.5% of immigrant minority households (5/8 HHs) were aware of varieties (**Figure 2**).

In addition, the earlier study presented that plant and animal diversities in agroforestry of the households in the Central Highlands were rich (about 69 plant and 11 animal types existed in all systems; an average of 2.94-5.51 plant types per household) (Tran & Tran, 2024). Some new worldwide studies also indicated the awareness of farmers on biodiversity in agriculture and agroforestry, including the diversity of indigenous plant varieties (Ali *et al.*, 2020; Phondani *et al.*, 2020).

Awareness of the households on fertilization

The study undertook the awareness of farmers on fertilization through the types of fertilizer they used and the cost of fertilization. Consequently, 59.3% of the interviewed households applied manure and microbial fertilizer (147/248 HHs), and 89.9% of the interviewed households applied chemical fertilizer (223/248 HHs), of which 44.4% households applied compound fertilizer (mixed N, P, and K, 12.5% households applied the mono fertilizer (only N, P, K separately), and 33.1% households applied both compound and mono-fertilizer (**Figure 3a** and **Figure 3b**).

Furthermore, indigenous minority households likely preferred using mono fertilizer (e.g. 16 out of 37 indigenous minority households applied chemical fertilizer, equivalent to 43.2%), while a few of Kinh's households used mono-fertilizer (e.g. 15 out of 178 Kinh's households, equivalent to 8.4%) (**Figure 3b**). Many farmers could not easily identify whether the compound fertilizer was quality or not, so mono-fertilizer were easier to identify, while there are hundreds of fertilizers in the markets and many of them are fake. Many households that applied the compound and mono fertilizer likely indicated their flexibility to deal with problems of markets in which they had a better awareness or better experience of fertilization.

Application of manure and microbial fertilizer were likely different between the households of ethnic groups (e.g. 14 out of 53 indigenous minority households - equivalent to 26.4%; 126 out of 187 Kinh's households - equivalent to 63.4%; and 7 out of 8 immigrant minority households - equivalent to 87.5% applied manure and microbial fertilizer) (**Figure 3b**). These households were likely aware of the

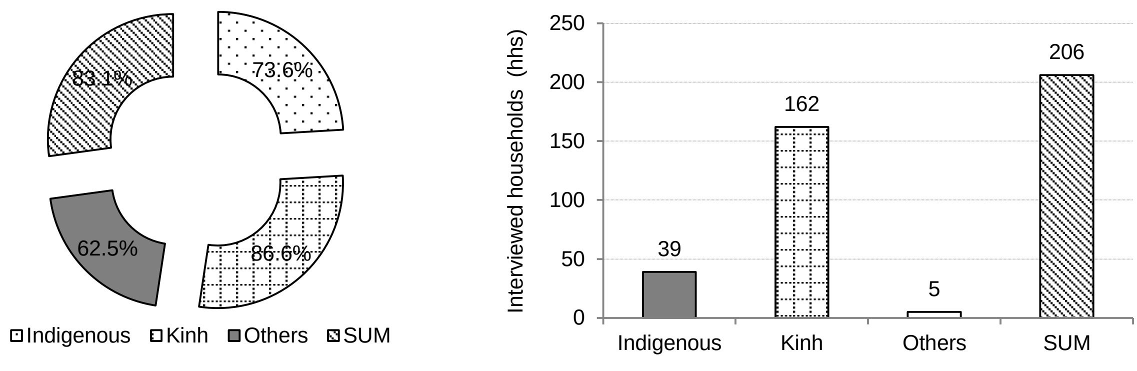


Figure 2. Awareness of the households on varieties of plants and animals at the study sites (a - percentage of household samples; b - numbers of households by ethnic groups) ($N_{indigenous}$ = 53; N_{kinh} = 187; N_{other} = 8; N_{total} = 248)

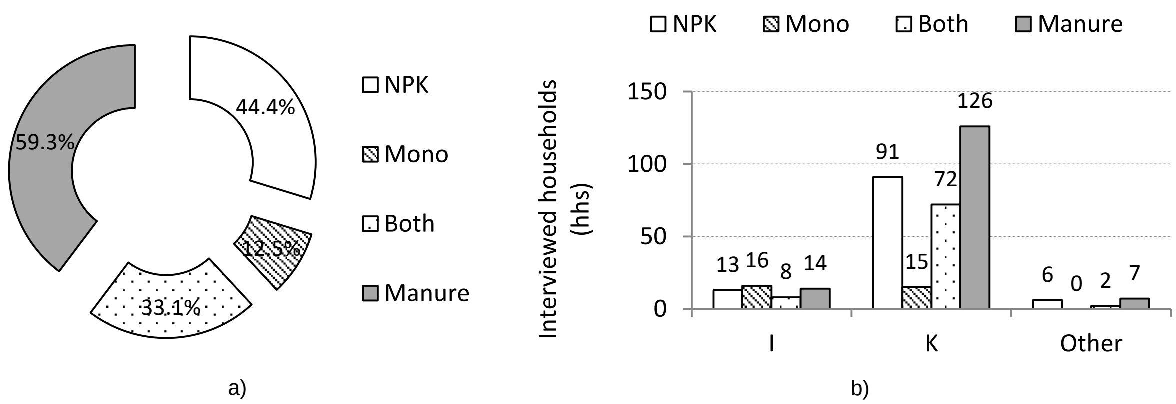


Figure 3. Types of fertilizer applied by the households in the study sites (a – percentage of households; b – numbers of households by ethnic groups) (NPK – HHs applied compound fertilizer; Mono – HHs applied single N, P, K fertilizer, separately; Both - HHs applied both compound and mono fertilizer)

significant roles of manure and microbial fertilizer in improving soil health, plant health, environment health, and human health (particularly, after long time intensive cultivation with a huge volume of chemicals).

To understand further, the times and costs that households spent for fertilization were also conducted. There was a large range of annual times of fertilising , and weredifferent between households. Average times applying fertilizer of

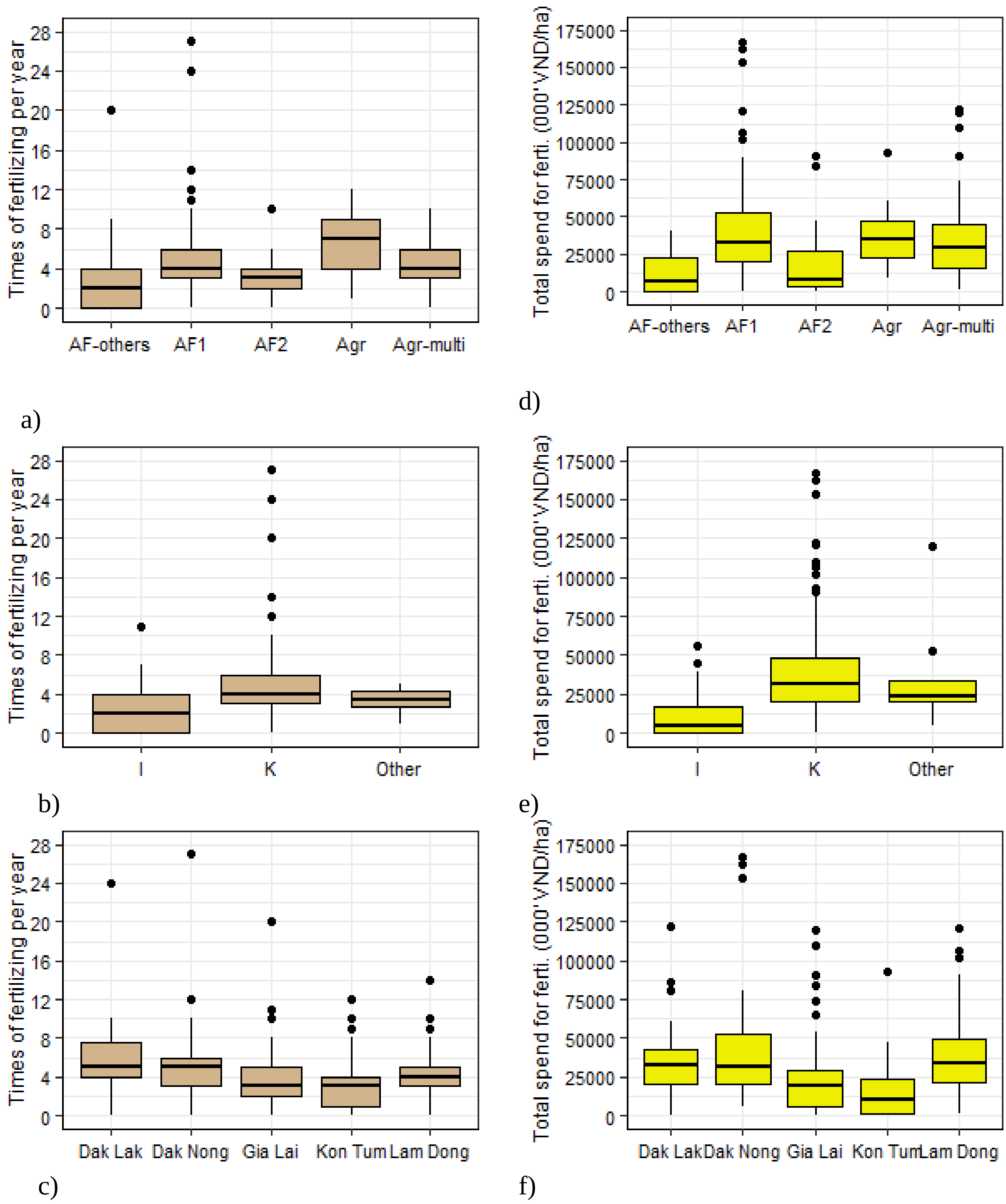


Figure 4. Average application times and spending for fertilization of households at the study sites (a, b, c - times of fertilization by cultivation types, ethnic groups, provinces; d, e, f - total spending money for fertilization by cultivation types, ethnic groups, provinces; One USD equivalent to VND 23,300).

the households cultivating AF-others, AF1, AF2, Agr, and Agr-multi were 2.94 (± 0.88); 5.15 (± 0.58); 2.35 (± 0.32); 6.09 (± 1.50); and 2.88 (± 0.36) times per year per household, respectively (**Figure 4a**). Therefore, it is likely that mono-agriculture took more times to fertilise than agroforestry. Within types of agroforestry, households cultivating AF1 spent more times for fertilization than others, ($\mathcal{X}^2$ = 20.57; *P* = 0.00038). The indigenous minority households, Kinh's households, and other minority households took 2.35 (± 0.68), 4.16 (± 0.31), and 2.88 (± 0.36) times per year per household, respectively (**Figure 4b**). So, Kinh's households took more times to fertilize than others, ($\mathcal{X}^2$ = 12.94; *P* = 0.0015).

The households in the provinces of Dak Lak, Dak Nong, Gia Lai, Kon Tum, and Lam Dong took 6.45 (± 0.73); 4.15 (± 0.53); 4.56 (± 0.75); 2.55 (± 0.47); and 1.21 (± 0.26) times per year per household, respectively (**Figure 4c**). and interviewed households in Dak Lak Province took more times for fertilization than households in other provinces ($\mathcal{X}^2$ = 66.91; *P* = $1.019e^{-5}$).

Regarding the costs of fertilization, the total cost for fertilization (including on the cost of fertilizer and labourers) of the interviewed households was also different. The households cultivating AF-others, AF1, AF2, Agr, and Agr-multi spent 13.37 (± 3.38), 43.51 (± 3.81), 16.88 (± 2.78), 37.65 (± 7.34), and 33.88 (± 2.86) million VND per ha per year , respectively (**Figure 4d**). Therefore, the households cultivating AF2 and AF-other paid less for fertilization than others (X2 = 49.51; P = $4.563e^{-10}$). The indigenous minority households, Kinh's households, and other minority households spent 9.94 (± 1.74), 39.06 (± 2.26), and 36.53 (± 12.82) million VND per ha per year, respectively (**Figure 4e**). So, the indigenous minority households spent less on fertilization than others (X2 = 70.44; P = $5.063e^{-16}$). The households in the provinces of Dak Lak, Dak Nong, Gia Lai, Kon Tum, and Lam Dong spent 38.49 (± 4.59), 43.03 (± 5.25), 26.88 (± 4.14), 15.70 (± 2.55), and 39.13 (± 3.67) million VND per ha per year, respectively (**Figure 4f**). So, households in the Gia Lai Province and Kon Tum Province spent less than those in the rest provinces (X2 = 45.89; P = $2.612e^{-9}$).

With manure and microbial fertilizer (not involving labour cost), households spent for AF-others, AF1, AF2, Agr, and Agr-multi were 3.69 (± 1.89), 12.46 (± 1.69), 4.39 (± 1.45), 7.06 (± 3.61), and 9.98 (± 2.11) million VND per ha per year, respectively (**Figure 5a**). So, the households cultivating AF1 spent much more on manure and microbial fertilizer than others ($\mathcal{X}^2$ = 25.57; *P* = $3.872e^{-5}$). The indigenous minority households, Kinh's households, and other minority households spent 2.15 (± 0.72), 11.32 (± 0.013), and 6.50 (± 2.42) million VND per ha per year, respectively (**Figure 5b**). So, the indigenous minority households spent less on manure and microbial fertilizer than others ($\mathcal{X}^2$ = 31,07; *P* = $1.791e^{-7}$). The households in the provinces of Dak Lak, Dak Nong, Gia Lai, Kon Tum, and Lam Dong spent 10.09 (± 1.92), 7.79 (± 1.61), 1.98 (± 0.72), and 12.68 (± 2.57) million VND per ha per year, respectively (**Figure 5c**). So, households in the Kon Tum Province spent less money on fertilization than those in other provinces ($\mathcal{X}^2$ = 31.38; *P* = $2.566e^{-6}$).

With chemical fertilizer (not involving labour cost), households spent for AF-others, AF1, AF2, Agr, and Agr-multi were 3.46 (± 1.19), 7.05 (± 1.18), 1.76 (± 0.39), 7.68 (± 1.98), 4.97 (± 0.76) million VND per ha per year, respectively (**Figure 5d**). while, the households cultivating AF2 spent less on chemical fertilizer than others, while households cultivating mono agriculture spent much more than others ($\mathcal{X}^2$ = 43.17; *P* = $9.533e^{-11}$). The indigenous minority households, Kinh's households, and other minority households spent 1.51 (± 0.39), 6.10 (± 0.67), and 5.71 (± 2.33) million VND per ha per year, respectively (**Figure 5e**), ($\mathcal{X}^2$ = 50.50; *P* = $1.081e^{-11}$). So, the indigenous minority households also spent less on chemical fertilizer than others. The households in the provinces of Dak Lak, Dak Nong, Gia Lai, Kon Tum, and Lam Dong spent 6.95 (± 1.13), 7.86 (± 1.95), 4.06 (± 1.05), 3.26 (± 0.77), and 3.46 (± 0.54) million VND per ha per year, respectively (**Figure 5e**), So, households in the Dak Lak and Dak Nong Provinces spent much more than households in Gia Lai and Kon Tum Provinces ($\mathcal{X}^2$ = 34.19; *P* = $6.821e^{-7}$).

Farmers likely invested more time and money in fertilization for mono cultivation than agroforestry. Kinh's households also invested more times and money for fertilization than other ethnic households. Additionally, farmers cultivating agroforestry also spent more money on manure and microbial fertilizer than chemical fertilizer indicating an important awareness of interviewed households in the Central Highlands.

Some studies in developing countries also indicated the awareness of farmers on fertilizer application behaviours, attitudes towards adopting better fertilizer application technologies, and environmental consciousness (Yang & Fang, 2015); and an acceptance of bio-fertilizer (Misiko *et al.*, 2011; Nanthini, 2017).

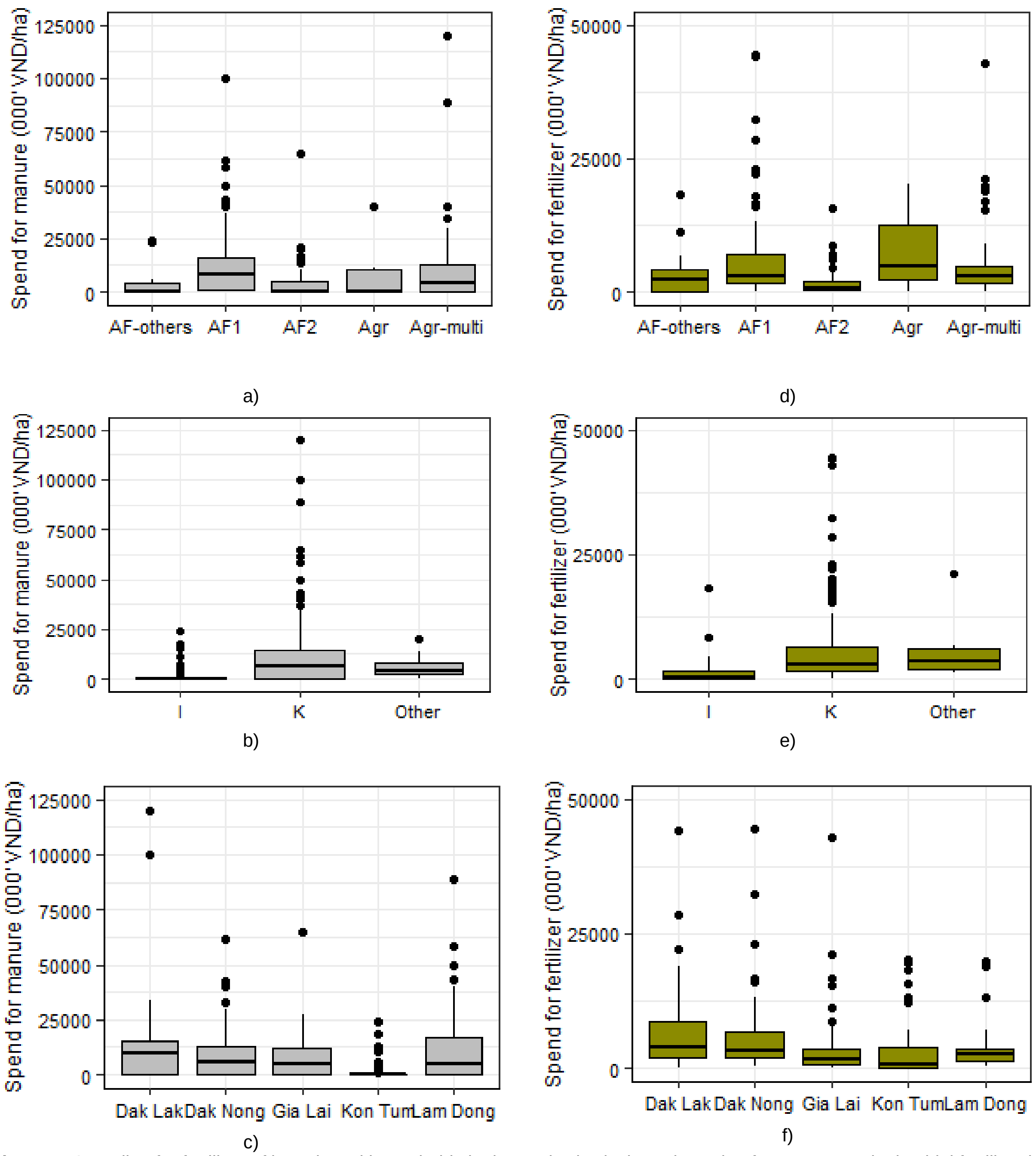


Figure 5. Spending for fertilizer of interviewed households in the study site (a, b, c - investing for manure and microbial fertilizer by cultivation types, ethnic groups, and provinces; d, e, f - investing for chemical fertilizer by cultivation types, ethnic groups, and provinces; One USD equivalent to 23,300 VND).

Awareness of the households on irrigation

Results show that 73.0% of interviewed households had irrigation systems, while 27.0% of the others did not apply any watering methods in their agriculture production system(**Figure 6a**). Applying irrigation systems of the indigenous minority households, Kinh's households and other minority households were 52.8% (28 out of 53 sampled Indigenous households), 77.5% (145 out of 187 sampled Kinh's households), and 100% (8 out of 8 sampled immigrant minority households) (**Figure 6b**). Watering by hand (with electricity or/and petrol pumps) was applied by almost all households because it was older technology, while sprinkler irrigation systems were applied by 46 households (of which 41 Kinh out of 46 households applied), and drip irrigation systems were applied by only 12 households (10 Kinh and 2 indigenous households) (**Figure 6c**).

By observation and open-ended interview questions, farmers were aware why to invest for irrigation in their intensive agriculture, particularly for cash crops. However, the indigenous minority households could not invest in water systems due to the limitations of family investment sources, a land location far from open water and/or electricity sources, and where they could not dig a well. Many Kinh people also identified the reduction of underground water resources, but better irrigation systems to save water was still less applied by broader farmers because of higher costs and less efficiency in small farms.

Highlands. The households that applied chemicals involving chemical pesticides (insecticide and fungicide), biopesticides, nutrients (liquid nutrients and plant hormones), and chemical herbicides were 83.9%, 3.6%, 13.7%, and 8.1% of interviewed households, respectively (**Figure 7a**). Also, the indigenous minority households, Kinh's households, and other minority households that applied chemical pesticides were 56.6% (30 out of 53 indigenous

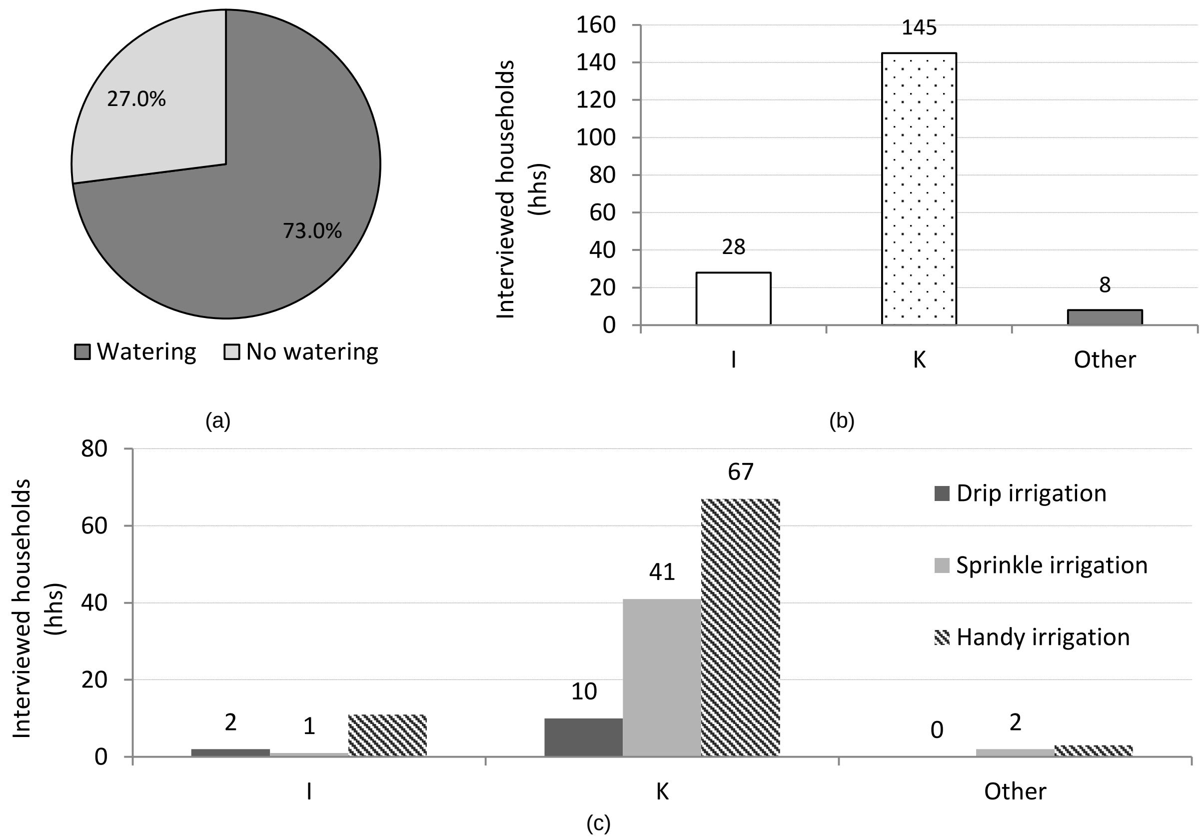
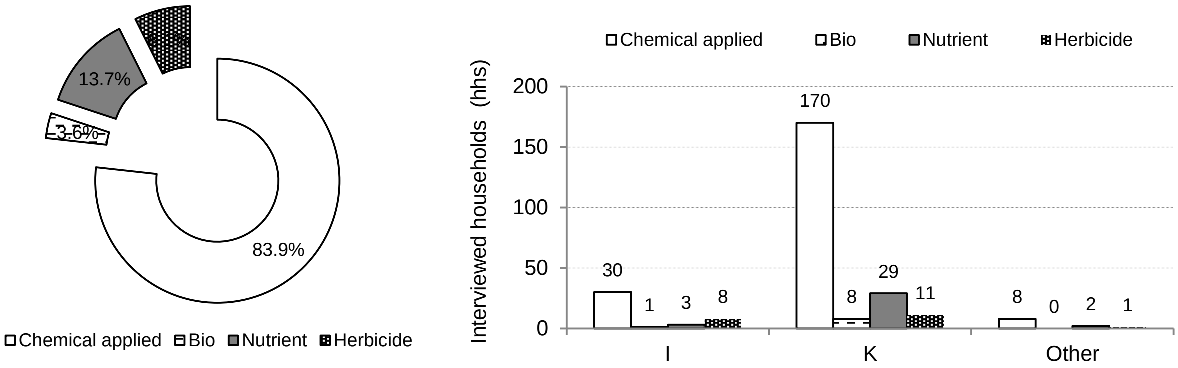


Figure 6. Households applying irrigation systems at the study sites (a - percentage of households; b - numbers of households by ethnic groups; c - numbers of households by ethnic groups and watering systems)



(a) (b)

Figure 7. Households applied pesticides and nutrients at the study sites (a - percentage of households; b - numbers of households by ethnic groups)

households), 90.9% (170 out of 187 Kinh's households), and 100% (8 out of 8 immigrant minority households), respectively. Besides, Kinh's households and minority households that applied nutrients and plant-controlled hormones were 15.5% (29 out of 187 Kinh's households) and 8.2% (5 out of 61 minority households), respectively. Although a few households applied chemical herbicides (e.g. 8.1% of sampled households), more indigenous households applied (e.g. 15.1% of indigenous households; while 5.9% of Kinh's households) (**Figure 7b**).

To understand further the situation, the study addressed the number of times and costs which households spent on pesticides, and results showed the differences between households of cultivation types, ethnic groups, and provinces.

Average number of times applying pesticides of the households cultivating AF-others, AF1, AF2, Agr, and Agr-multi were 2.82 (± 1.24), 3.81 (± 0.36), 2.08 (± 0.32), 4.18 (± 1.16), and 4.3 (± 0.40) times per year per household, respectively (**Figure 8a**). Therefore, it is likely that mono agriculture took more times to use pesticides than agroforestry (χ^2 = 24.03; P = 7.874e^{-5}). The indigenous minority households, Kinh's households, and other minority households took 1.87 (± 0.50), 4.02 (± 0.24), and 3.75 (± 1.10) times per year per household, respectively (**Figure 8b**). So, Kinh's households took more times to use pesticides than others, (χ^2 = 35.39; P = 2.07e^{-8}). The households in the provinces of Dak Lak, Dak Nong, Gia Lai, Kon Tum, and Lam Dong took 4.10 (± 0.53), 3.71 (± 0.36), 3.17 (± 0.63), 1.98 (± 0.40), and 4.71 (± 0.44) times per year per household, respectively (**Figure 8c**). The interviewed households in Kon Tum Province took less times to use pesticides than households in other provinces (χ^2 = 33.34; P = 1.018e^{-6}).

When looking at the costs of applying pesticides, the households cultivating AF-others, AF1, AF2, Agr, and Agr-multi spent 0.98 (± 0.35), 2.32 (± 0.25), 1.57 (± 0.55), 2.09 (± 0.84), and 3.00 (± 0.37) million VND per ha per year, respectively (**Figure 8d**). Therefore, the households cultivating AF2 and AF-other paid less for using pesticides than others (χ^2 = 33.42; P = 9.81e^{-7}). The indigenous minority households, Kinh's households, and other minority households spent 0.57 (± 0.14), 2.75 (± 0.24), and 2.26 (± 0.59) million VND per ha per year, respectively (**Figure 8e**). and, the indigenous minority households spent less on using pesticides than others (χ^2 = 48.71; P = 2.64e^{-11}). The households in the provinces of Dak Lak, Dak Nong, Gia Lai, Kon Tum, and Lam Dong spent 2.39 (± 0.35), 2.90 (± 0.36), 2.00 (± 0.59), 0.80 (± 0.18), and 3.21 (± 0.50) million VND per ha per year, respectively (**Figure 8f**). households in the Dak Nong Province spent more money on using pesticides than households in the other provinces (χ^2 = 45.57; P = 3.021e^{-9}).

While most farmers applied a wide range of chemicals to protect and control crops, many farmers were unaware of better technologies such as bio-pesticides and nutrients. Significantly, a few households applied herbicides that could be positive information for the potential of agricultural product safety in the regions. Kinh's households likely used pesticides

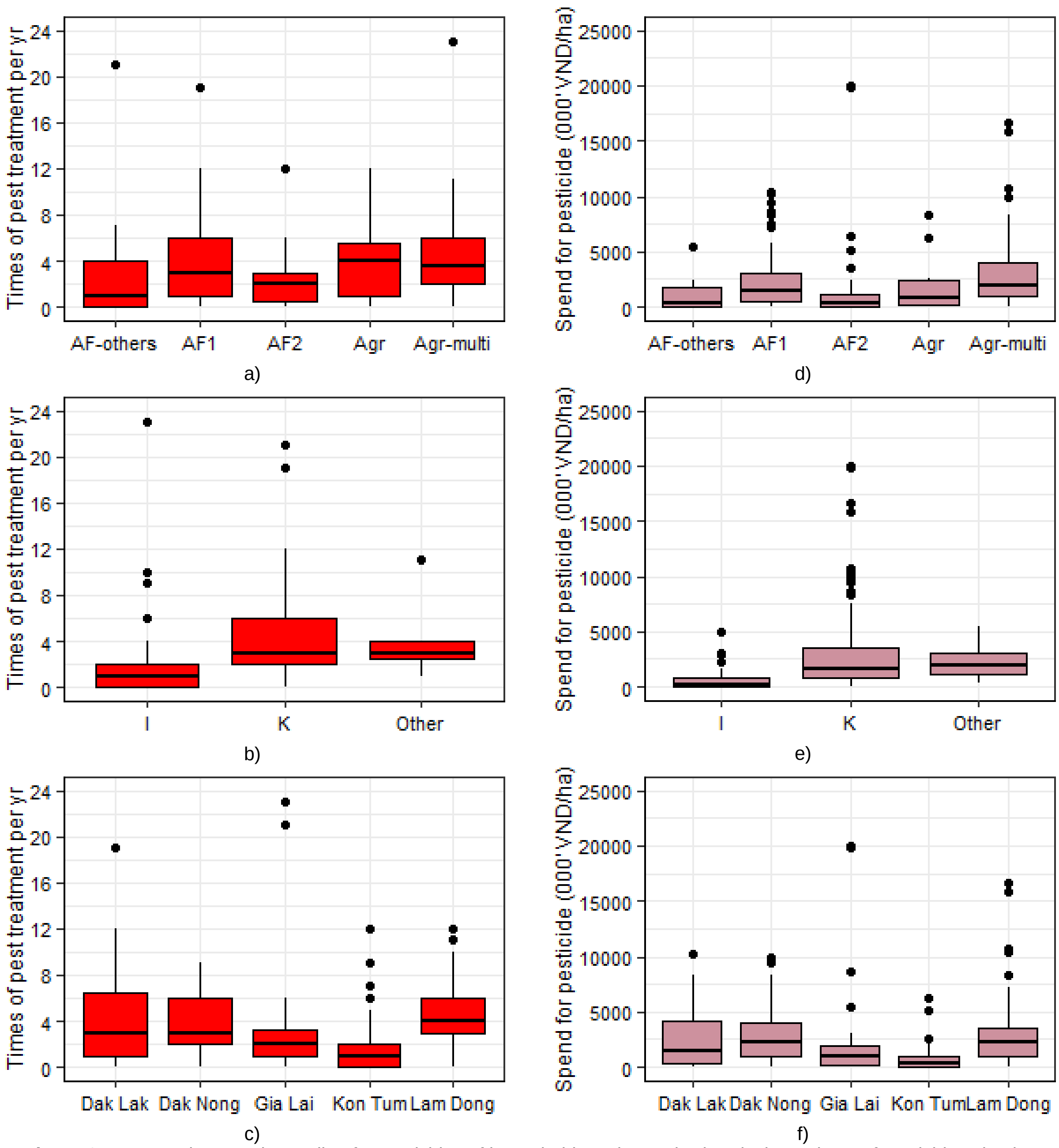


Figure 8. Average times and spending for pesticides of households at the study sites (a, b, c - times of pesticide using by cultivation types, ethnic groups, provinces; d, e, f - total spending money for pesticides by cultivation types, ethnic groups, provinces; One USD equivalent to 23,300 VND).

more than other minority households, and households cultivating agroforestry used fewer pesticides than households cultivating mono-crop or multi-crops.

Studies on the levels of knowledge and awareness of the dangers to the environment and human health affected by using chemical pesticides in China provided further understanding of farmer's responses (involving males and females, particularly) (Yang *et al.*, 2014; Wang *et al.*, 2017). Furthermore, agricultural chemicals are linked closely to food safety which farmers should be aware of, so Good Agricultural Practices (GAP) and organic farming could be a consideration (Joshi *et al.*, 2019; Yanakittkul & Aungvaravong, 2020) that is important for policymakers, training, and extension.

Conclusions

In summary, some simple agri-technologies that households in the Central Highlands have applied in their farms include plant varieties, animal varieties, drip irrigation, sprinkle irrigation, handy irrigation, greenhouses, semi-processing, and others. Overall, 55.2% of the surveyed households were aware of irrigation, while less than 33.1% of responders had an awareness of the other technologies. By types of cultivation, the average numbers of technologies households applied in AF-others, AF1, AF2, Agr, and Agr-multi were 1.90 (± 0.31), 1.57 (± 0.09), 1.24 (± 0.11), 1.67 (± 0.33), and 2.05 (± 0.15) technologies per household.

Focusing on the awareness of the responders on varieties, fertilizer, watering, and chemicals in the Central Highlands, the study conclusions are the following:

(i) For varieties, 83.1% of interviewed households gave perception on varieties of plants and animals which applied in the farms;

(ii) For fertilizer, 59.3% of the households applied manure and microbial fertilizer, and 89.9% of the households applied chemical fertilizer; Households spent 3.46 (± 1.19), 7.05 (± 1.18), 1.76 (± 0.39), 7.68 (± 1.98), 4.97 (± 0.76) million VND per ha per year for AF-others, AF1, AF2, Agr, and Agr-multi;

(iii) For irrigation, 73.0% of households applied irrigation systems, while 27.0% of the rest did not apply any watering methods in the farms;

(iv) For chemicals, 83.9%, 3.6%, 13.7% and 8.1% of interviewed households responded on chemical pesticides, biopesticides, nutrients, and chemical herbicides. Average times applied pesticides for AF-others, AF1, AF2, Agr, and Agr-multi were 2.82 (± 1.24), 3.81 (± 0.36), 2.08 (± 0.32), 4.18 (± 1.16), and 4.3 (± 0.40) times per year per. And costs of applying pesticides for AF-others, AF1, AF2, Agr, and Agr-multi spent 0.98 (± 0.35), 2.32 (± 0.25), 1.57 (± 0.55), 2.09 (± 0.84), and 3.00 (± 0.37) million VND per ha per year.

Despite the simple technologies that have been used for a long time, other new or high technologies were poorly adopted by households in the Central Highlands of Vietnam because of lack of awareness. Lack of knowledge in high technologies of the farm households is a big gap that should be given consideration by policymakers, training organisations, and Extension when making recommendations.

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