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Assessment of vulnerability of climate change on crop and livestock production, adaption in Vietnam

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ABSTRACT

This research presents the impacts of prioritized climate change adaption options for crop and livestock production. Vietnam is one of the most vulnerable countries to the effects of climate change. The sector, comprising of 2 main sub-sectors has been affected seriously by climate change with high VI index (from 0.448 to 0.605 on crop, from 0.201 to 0.396 to livestock production). Adaptive measures (SRI, IBM, VGP, ICP, LCT, ICH, GFC,..) from crop, animal livestock have lower cost and higher benefits in comparison with conventional model, especially VietGAP pomelo, integrated coffee, integrated maize and bean, system of rice intensification; local chicken with high tolerance, improving cattle house for pig and biogas; green forage crop.

Key words : *Vulnerable, Agriculture, Crop, Livestock and aquaculture.*

Introduction

Vietnam's extensive coastline, vast deltas and floodplains, and location on the path of typhoons and the Southeast Asian monsoon expose many parts of the country such as the low-lying Red River and Mekong River Deltas to sea level rise and climate-induced extreme weather events. Over the past 50 years, Vietnam has experienced a 20cm rise in sea level and a 0.5°C increase in average temperature. The scenario of climate change and sea level rise for 2100 published by Vietnam Government in 2012 has projected an additional 2-3°C mean temperature rise and a 57-73 cm sea level rise (Ministry of Natural Resources and Environment of Vietnam, 2011). Disasters, the majority of that was climate-related, already cause an annual economic loss equivalent to 1.5% of gross domestic product (GDP) (Ministry of Natural Resources and Environment of Vietnam, 2011). Agriculture sector in Vietnam, which relates directly to the lives of more than 75% of the country population, is particularly dependent on climate (Antle *et al.*, 2016).

This study will contribute to focus on in-depth analysis of vulnerable subsectors of agriculture, namely crop, livestock; to identify cost-effective climate change adaption actions of crop, livestock for integration in Vietnam.

Materials and Method

The general methodology based on a review of available guidelines and methodologies applied in related studies (Bourgoin *et al.*, 2016).

Elements of the methodology for conducting study would include: Desk-study and use of secondary-data and relevant information for reviewing and assessment; relevant information gathering and application of participatory appraisal and expert review to screen and develop the list of adaptation

measures; questionnaires and field survey to collect input data and impact assessment of selected key adaptation measures; participatory and expert consultation workshops and meetings to develop the study methodology and work plan, review results.

Vulnerability index (VI) was constructed functions of exposures (normally posstive impacts), sensitvity (almost possitive impacts) and adaptive capacity (alway negative impacts on VI) on crops, animal livestock. It varied from zero (no climate change vulnerable) and 1 (maximum climate change vulnerable) (Thornton *et al.*, 2007).

The positive functional relationship with vulnerability on crops, animal livestock were normalized and calculated by:

$$xij = \frac{Xij - Min\{Xij\}}{Max\{Xij\} - Min\{Xij\}}$$

The negative functional relationship with climate change vunerability on crops, animal livestock were normalized and estimated by Equation.

$$yij = \frac{Max\{Xij\} - Xij}{Max\{Xij\} - Min\{Xij\}}$$

Xij, Yij are the statistical values observed for the jth component of the ithregion; MaxXij and MinXij are applied to the maximum and minimum values of the j^{th} components for the i^{th} region.

VI for all subsector was estimated by way:

Simple average of the scores: When equal weights are given we use simple average of all the normalized scores to construct the vulnerability index by using the formula.

$$VI = \frac{\sum_j xij + \sum_j yij}{K}$$

Estimate financial costs and relevant costs for each adaptation option from field survey:

$$C = C_o + \Sigma_{i=1}^{n} C_i$$

In which:

C_0: fixed cost

C_t: Variable costs (including opportunity cost, etc.)

Estimate relevant benefits from each adaptation measure from field survey:

$$B_t = \Sigma_{i=1}^{n} R_i$$

Develop equations and calculate NPV, FV of each adaptation measure from field study:

$$NPV = \sum_{i=1}^{n} \frac{B_t - C_t}{(1+r)^t}$$

Estimate total benefit from each potential adaptation measure:

$$FV = B_t(1+r)^t$$

Sensitivities analysis with suitable selection of discount rate (%) according interest from central commercial bank.

Results and Discussion

Firstly, climate vulnerability analysis to crop production were applied for rice, maize, cassava, surgarcane, coffee and fruit at district level from all provinces of Vietnam based on the available data sources that were collected from statistical offices and relevant data sources (Fig. 1).

Rice is the most important crop and has been cultivated in almost all districts of Vietnam. It is the most important agroecosystem for rice production

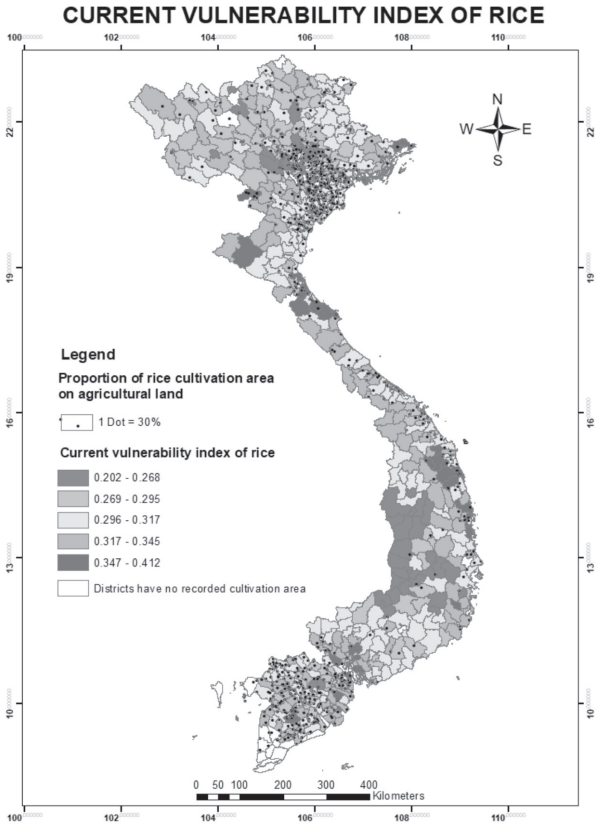

Fig. 1. Overlayed rice density and VI on rice production (2012-2018)

in Vietnam. The VI calculation from 706 districts of 63 provinces shown that the top 20 highest vulnerable districts varried from 0.358-0.412. Hoai An (Binh Dinh), La Gi (Binh Thuan), Ham Tan (Binh Thuan), An Nhon (Binh Dinh); Ba Tri (Ben Tre), Phu My (Binh Dinh), Sam Son (Thanh Hoa), Duc Pho (Quang Ngai), Son Ha (Quang Ngai), Thach Ha (Ha Tinh) were determined as the highest climate vulnerability on rice production. In typical province, most of the districts with high vulnerability are located in Quang Ngai and Ha Tinh (even VI was more than 0.4). In Quang Ngai, climate change causes heavy rainfall in the flood season, which causes flooding and drastic fall in the dry season leading to a further shortage of water and saline intrusion into the river. Land resources in Quang Ngai province are at an increased risk of salinization and salinity intrusion, erosion and sedimentation, coloration, hardening and desertification. In agriculture, the area of agricultural land is in danger of inundation, the demand for water increases and crop yields are significantly reduced (Ministry of Agriculture and Rural Development of Vietnam, 2016).

Maize is the second important food crops and be high vulnerability. The top ten of the highest climate vulnerable districts are Ham Tan (Binh Thuan), La Gi (Binh Thuan), An Hoai (Binh Dinh), Phu My (Binh Dinh), Da Bac (Hoa Binh), An Lao (Hai Phong), Quang Binh (Ha Giang), Minh Long (Quang Ngai province). Maize received high VI than rice (0.462-0.541) because of depending ecological features, especially in sloping land for maize cultivation.

The highest climate vulnerable districts for cassava production mainly focussed on districts are Ham Tan, La Gi (Binh Thuan), Hoa Nhon, An Nhon, Phu My (Binh Dinh), Minh Long, Ha Son and Ba To (Quang Ngai), Quang Binh, Bac Quang (Son La) (VI: 0.511-0.605). According to the plan of cultivation of Binh Dinh province to 2025, with orientation to 2030, this province will develop stably 11,000 ha of cassava. However, by early 2018, the cassava area in the province has exceeded 12,500 ha. Most of the cassava area in Binh Dinh is extensive, not invested properly care, so the yield is only about 264 quintals/ha. In addition, hot weather was too harsh for many months without rain, leading to cassava dead series. In Dak Lak, prolonged droughts due to the effects of climate change make many areas of crops severely damaged. In addition, the irrigation system (irrigation water for about 60% of the crop area). The risk of water shortages (including surface and groundwater) is threatening the development of crops in the area.

Districts in Da Nang, Binh Thuan and Binh Dinh have the highest vulnerability index in sugarcane production with VI index greater than 0.4 (0.448-0.512). Most of the districts with high vulnerability are located in Quang Ngai and Thanh Hoa. Currently, Thanh Hoa is the province leading the country in sugar cane production with 4 sugar factories with a total capacity of 19,000 tons of cane per day. The annual average sugarcane area is about 30,000 ha. Average yield is about 60 tons/ha, yield of sugarcane is 1.7-2 million tons/year. Some of the reasons leading to low productivity from the lack of synchronized sugarcane cultivation techniques, the mechanization of sugarcane production is still low, especially in terms of harvesting and labor pressure. (labor usually accounts for 18 - 20% of cost).

Districts in Dong Nai, Dak Lak and Lam Dong have the highest vulnerability index in coffee production with VI index greater than 0.4 (0.448-0.518). Among the provinces in the Central Highlands, Dak Lak province has the highest vulnerability index in coffee production. According to the Fourth Report of the Intergovernmental Panel on Climate Change (IPCC), Vietnam is one of the five countries most affected by climate change, and Dak Lak is one of provinces affected severely. According to data from Dak Lak Department of Agriculture and Rural Development: From 1996 to 2011, the annual loss from natural disasters in Dak Lak was more than 681 billion VND, of which losses caused by drought accounted for 80%. At the same time, changes in humidity and other climatic conditions also result in yield and yield of the crop (Nhan *et al.,* 2011).

Among the provinces in the midland and northern mountainous, Son La province has the highest vulnerability index in coffee production. Son La is the second largest grower of Arabica coffee in Vietnam. In the province, there are some cold and frosty seasons at the end of the year causing the productivity of coffee to be affected.

Districts in Binh Thuan, Binh Dinh, Ha Giang and Ben Tre have the highest vulnerability index in fruits production with index from 0.492 to 0.547.

Secondly, climate vulnerability analysis to animal livestock production. The VI was estimate for pig, poultry, cattle, buffalo and dairy production and agreegared animal livestock. The VI was calcu-

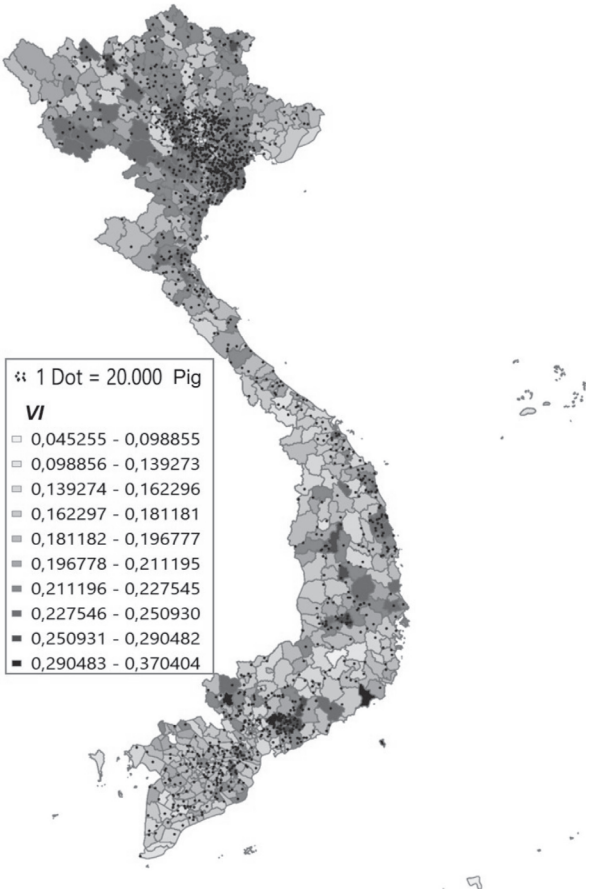

Fig. 2. Overlayed pig density and VI on pig production (2012-2018)

lated for 706 districts over 63 provinces (Fig. 2).

To pig production, 20 districts shown the highest VI (0.259-0.370) belong to 10 provinces including Binh Thuan (2), Ha Tinh (1), Ha Nam (2), Dong Nai (4), Hanoi (2), Thai Binh (2), Nam Dinh (2), Lao Cai (1), Dak Lak (1), and Gia Lai (2). The results showed that Dong Nai seemed to be the most vulnerable for pig production with 4 districts having the highest VI, following by Nam Dinh, Ha Nam, Binh Thuan, Thai Binh, Gia Lai and Hanoi provinces those were quite vulnerable with 2 districts shown the highest VI values. While almost the central districts of big cities such as Ho Chi Minh city, Hai Phong, Hanoi, Da Nang, and island districts were shown the least vulnerability as no or very few pigs kept there.

To poultry production, 20 districts shown the highest VI (0.273-0.396) belong to 13 provinces including Binh Thuan (2), Tay Ninh (3) Dong Nai (4), Thanh Hoa (1), Dak Lak (1), Ha Nam (1), Hanoi (2), Gia Lai (1), Tien Giang (1), Phu Yen (1), Quang Ngai (1), Thai Binh (1), and Son La (1).

To cattle production, 20 districts having the highest vulnerability index for cattle production (0.235-0.362) belong to 15 provinces including Binh Thuan (2 districts), Tay Ninh (1 district), Ha Nam (1 district), Thanh Hoa (1 district), Dong Nai (3 districts), Hanoi (2 districts), Gia Lai (2 districts), Kien Giang (1 district), Bac Lieu (1 district), Tien Giang (1 districts), Thai Binh (1 district), Son La (1 district), Dak Lak (1 district), Nghe an (1 district), and Vinh Phuc (1 district). Those districts and provinces have big or moderate cattle herds but cope with quite strong climate change such as increase in drought duration or cold winter affecting the green feed resource for cattle.

To buffalo production, 20 districts having highest VI for buffaloes (0.234-0.329) belong to13 provinces including Binh Thuan (2 districts), Bac Lieu (1 district), Tay Ninh (1 district), Ha Nam (1 district), Dong Nai (2 districts), Kien Giang (1 district), Gia Lai (1 district), Son La (1 district), Hoa Binh (3 districts), Lao Cai (1 district), Nghe An (2 districts), Thanh Hoa (2 districts), and Tuyen Quang (1 district).

The results showed that Hoa Binh, Binh Thuan, Thanh Hoa, Nghe An, and Dong Nai provinces are quite vulnerable for buffalo production with 2 districts having high VI. While number of districts of Ca Mau province, An Minh and Kien Hai district of Kien Giang, Cho Lach district of Ben Tre as well as the central districts of Ho Chi Minh City, Hanoi, and Hai Phong cities were shown as the least vulnerable districts for buffalo production. Those districts have no or small buffalo herds.

To dairy production, 20 districts have shown the highest VI for dairy (0.221-0.366) belong to11 provinces including Binh Thuan (3 districts), Tay Ninh (2 districts), Ha Nam (1 district), Dong Nai (4 districts), Ha Tinh (1 district), Gia Lai (1 district), Son La (1 district), Hanoi (3 districts), Lao Cai (1 district), Thai Binh (2 districts), and Hai Duong (1 district). The results showed that Binh Thuan, Dong Nai, Hanoi and Thai Binh provinces are quite vulnerable for dairy production with a number of districts having the highest VI. In general, the map shows that high VI for dairy production could be seen in numbers of districts, mainly located in the northern part of the country.

To agregated livestock production, among 20 districts shown the highest vulnerability index (0.201-0.311) belong to 15 provinces including Ha Tinh (1

district), Thanh Hoa (1 district), Dak Lak (1 district), Tien Giang (1 district), Ha Nam (1 district), Vinh Phuc (2 districts), Thai Binh (1 district), Phu Tho (1 distict), Hanoi (2 districts), Bac Giang (3 districts), Binh Thuan (1 district), Ben Tre (1 district), Bac Lieu (1 districts), Nghe An (1 district), and Ho Chi Minh city (2 districts).

The results showed that Bac Giang, Vinh Phuc provinces, Hanoi and HCMC are quite vulnerable with 2 to 3 districts shown the highest VI value. While almost the central districts of big cities including Ho Chi Minh city, Hai Phong, Hanoi, Da Nang, Da Lat and Ca Mau were shown the least vulnerability, and no or very few livestock have been kept there.

Thirdly, cost analysis from adaptive measures in crop production. Costs for System of Rice Intensification (SRI) was lover than conventional model because farmer' used less seed (31.3% - 70.1% less than conventional model, depending cultivated season and provinces (Binh Dinh, Ha Nam and Ben Tre province); less 6.42% to 18.8% of nitrogen fertlizer per hectare in comparison with normal rice and leaded to reduce costs 12.4% to 39.1% from SRI in comparison with normal rice. Intercroping maize and bean (IMB) has higher costs than monoculture maize because of cost for bean. Higher cost mainly come from land preparation for bean, seedling, chemical fertilzer, weed control, pest management, harvesting cost (if family labor not available). It may concern as problem for farmers with less family labor to invest for IMB as adaptive measures (Fig. 3).

Intercroping maize and bean (ICP) is also good adaptive measures in sloping land of Son La provinces to response to drought and low fertility soil. Because of sloping land cultivation, ICP has low cost, only 26.27 million per hecare, higher than cassava monoculture because of added peanuts investment.

VietGAP of pomelo (VGP) have high cost (136.39 million VND per hectare per year), higher than non-VietGAP pomelo because of more cost to investment for machines, manure ad organic fertilizer, microorganice fertilizer, pest control and fruit packaging. However, VietGAP pomelo was also lower costs of weeding, pesticide in use and water irrigated expenditure. It can be seen that poor farmers who have limited financial sources could not enough capacity to apply VietGAP pomelo.

Coffee is the most important crop , Integrated coffee cultivation (IcoM) expent high cost than conventional model (191.48 million VND per hectare for ICoM vs. 88.42 VND per hecare, incldluing discount rate at year 5th). The higher cost mainly come from manure and organic fertlizer in use in both Son La and Dak Lak province while it was not clear reduction in chemical fertlizers and pesticide in use until the time of field surveyed.

Fouth, revenue analysis from adaptive measures in crop production. SRI provided higher rice yield significanly from surveyed 30 farmer's households per each site. It can be shown in the figure that total rerenue from SRI was about 83.75 million per year while it only 73.68 million per year from normal rice. Hence, it can be seen that SRI not only provided lower cost but also higher revenue (Fig. 4).

IMB has one more harvest from bean, hence, total revenue from IMB was 66.98 million per hectare per year, abmost double in comparison with maize monoculture only. Together higher revenue, IMB also helped farmers weed controls and humididy maintainences for next maize.

Although high costs for VietGAP pomelo, it also

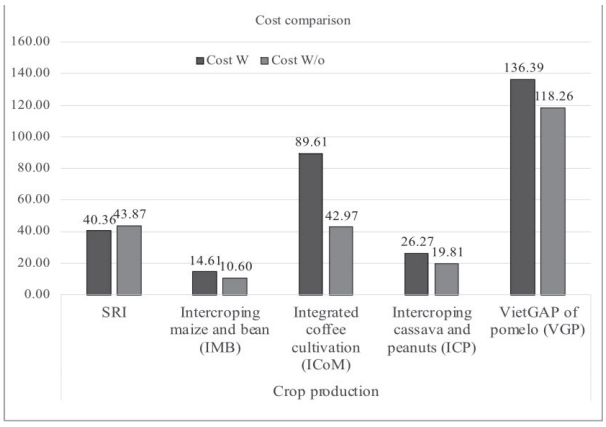

Fig. 3. Cost comparison

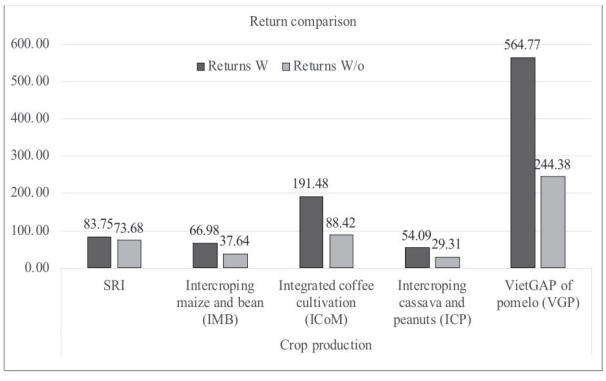

Fig. 4. Revenue comparison

produced much higher in revenues (564.6 million VND per year for garden at year firth (more than double times in comparison with non-VietGAP pomelo). Beside with higher revenue, VietGAP pomelo help pomelo have longer life and well growth.

The cost among ICoM was not clear differences with conventional model but according the field survey, coffee from ICoM trended higher harvested yield, led to higher revenue (191.47 million VND per hectare vs 88.72 million VND per hectare on average). Hence, according to the field survey, ICoM produced more incomes than conventional model.

The end, analysis from adaptive measures in crop production. On average, SRI holders earned 36.56 million VND per hectare per years (51.6% to return, 2.09 VND of revenue per each 1 VND of cost); higher from 16.6-25.1% in comparison with normal rice (39.66% and 1.68 times, respectively).

It can be seen that IMB produced 52.37 million per hectare per year, whole maize monoculture was only 27.04 million VND per hectare. Farmers with IMB earned 4.58 VND per each VND of cost, 78.19% of return to costs, higher than monoculture maize (3.55 and 71.85%). In addition, IMB and maize cultivation have low costs and high benefit to farmers according to field surveyed from Son La province. Farmer earning 421.96 million VND per hectare from VietGAP pomelo while the other obtained only 122.65 million VND per hectare per year due to high yield and prices from VietGAP pomelo. Hence, VietGAP pomelo is good adaptive measures to help farmers earned more money from pomelo exportation. The field surveyed result in Ben Tre province shows that each cost was invested for VietGAP pomelo, farmers earned 4.14 VND of revenues (2.07 VND from non-VietGAP pomelo), percentage to return was 74.71% because of low discount rate and annual mainternance. ICoM measures provided good benefits in comparison with conventional coffee (101.86 million VND per hectare from ICoM vs. 45.45 million VND per hectare), BCR was 2.14 times for ICoM while it was only 2.06 from conventional coffees, percentage to return was 53.21% for coffees from ICoM at year 5-7th.

Cost analysis from adaptive measures in animal livestock. It was different to apply cost and revenue calculation. Based on the field surveys from 136 pig raining households, 143 chicken raising farmer households and 55 cattle raising households, the cost and revenue calculation was converted to same scales of animal heads, e.g. 250 pig heads, 5000 chicken birds and 15 cow heads to compare in pairs with climate change adaptive and conventional animal livestock. The cost analysis as the following:

On avereage, cost for raising 5000 chicken that were raised by local chicken with high tolerances (LCT) was 512.74 million per years, much higher than coventional model because they have invested for improved houses and higher varieties (only 379.33 million VND per year for 5000 birds from conventional chicken. Because quality and price from local genotype is quite difference, hence, cost do not say any think among LCT and conventional chicken. The cost of Improving cattle house for pig and biogas (ICH) was about 878.12 million VND per 250 heads (100kg/head) per year, on average, about 35.1 thousand VND per kg of live pig, lower than conventional pig rainings beause of lower feeding costs per kg, ICH helped pib can developed faster and reduced feed efficiency (Fig. 3).

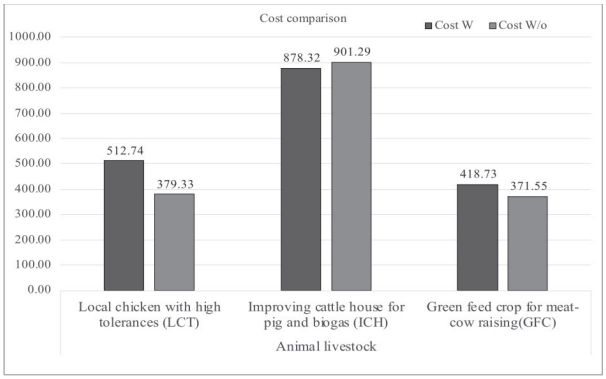

Fig. 3. Cost comparison

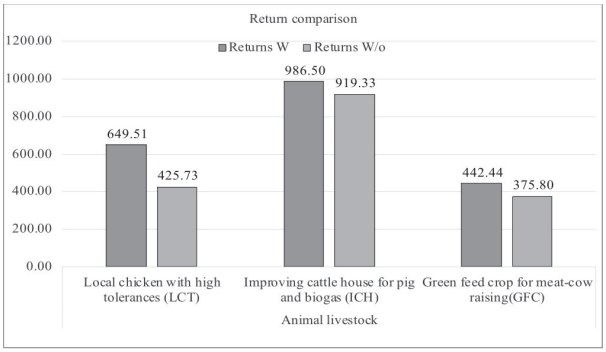

Fig. 6. Reterun comparison

However, its cost seem higher than conventional cattle raising according to field survey in Thanh Hoa, Binh Dinh and Ben Tre provinces. It can be seen that total cost from 15 cows that feeded by

green feed crop for meat –cow raising (GFC) technology was 418.73 milions per households (27.91 million VND per heads upto selling period) while it was only 24.76 million VND per heads from conventional cow because of more expenditure for concentrated feeds and green forage preparation.

Revenue analysis from adaptive measure in animal livestock. In fact, LCT has higher cost but the prices was higher, than, farmers earned more than 649.51 million for 5000 chicken from LCT while conventional chicken provided only 425.73 million (included risks and mortabiliry rate). It is hard to say about revenue at the surveyed times (2017) because farmers faced difficulties to lower price below cost production, some time, the prices of live pig was less than 25 thousand VND per kg, whenever, the cost production was 35.1 thousand VND per kg. Hence, the team applied average price in distance of 2016 and 2018 to calculate revenue from pigs that feeded by ICH (Fig. 4).

Because weight of selling cow from GFC was higher than conventional cows by the same time at selling, hence, farmers earned more revenue (442.44 million VND per 15 heads from GFC and 375.80 million VND per 15 heads from conventional cow).

Conclusion

The study updated and estimated VI for 706 districts for crop production, animal livestock concluded that (i) the most 20 climate vulnerable districts on rice varied VI from 0.358 to 0.412; maize from 0.462 to 0.541; cassava from 0.511 to 0.605; sugarcane from 0.448 to 0.512; coffee from 0.448 to 0.518; fruit from 0.492 to 0.547. To livestock, climate vulnerable districts on pig from 0.259-0.370, 0.269-0.396 on poultry, 0.235-0.362 on cattle production; 0.234-0.329 on buffalo; 0.221-0.366 on dairy cow; and 0.201-0.311 on animal livestock, the climate vulnerability index on animal in particular and in livestock in general located in low and medium; Almost adaptive measures from crop, animal livestock (SRI, IBM, VGP, ICP, LCT, ICH, GFC,..) have lower cost and higher benefits in comparison with conventional model, especially VietGAP pomelo, integrated coffee, integrated maize and bean, system of rice intensification because farmers used less seeds, less of nitrogen fertilizer per hectare or less labor. These are good adaptive measures to climate change.

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