Improvement of On-farm Management for Effective Use of Water Resource From Small-scale Irrigation Schemes in Northern Mountainous Areas in Red River Basin

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Abstract

Although water for crops has always been considered the decisive factor for the success of agricultural production, use of water sources from irrigation systems in Vietnam northern mountainous region has not been exploited accordingly to potential of the land on hilly slopes. The main cause of ineffective exploitation of the schemes in these areas is the lack of scientific and technical solutions in water resources exploitation as well as nonconformities during cultivation.

The purpose of this study is to analyze measures that facilitate efficiency of water resources use for hilly land areas from small-scale irrigation works as well as identify factors hindering or shortcoming during implementation process.

The cases study selected are model of farmer group planting medicinal crop in Te Le commune, Tam Nong district, Phu Tho province and model of farmer group planting orange trees in Bac Phong commune, Cao Phong district, Hoa Binh province. Site survey combining with interview was conducted in 2015 in 2 cases study. So far, findings from practical models and desk study review have been analyzing and synthesized to achieve the set objectives.

Advanced irrigation techniques combined with suitable water sources management through operation of farmers’ groups are applying in models site. The required amount of water for upland crops is less than that of water needed for rice cultivation (saving 35% of water amount in comparison with traditional farming manner); existing irrigation works are fully able to irrigate larger areas of
upland crops, instead of being not enough water for smaller of rice as before. Efficiency of water use from these works increased up to 17%, income of farmers improved and they have not depended much on rainfall water as before.

Hilly land in Vietnam, accounting for over three quarters of the natural land area, is the resource with great potential in agricultural production. Small-scale irrigation in combination with suitable plantation solutions can be applied easily in the sloping farming areas have irrigation systems but inefficiently operated, which support sustainable production, soil conservation and erosion control for cultivation on slopes. It can also be applied for various plants.

**Problem statement**

To enhance operation efficiency of existing irrigation works to better serve for agricultural production, socio-economy and environmental protection is indicated as the most important task of water resources sector in Vietnam, particularly in the context of further cuts of public investment to macroeconomic stability under Resolution no. 11 of the Government dated 24/2/2011.

Currently, the Scheme on restructuring the water resources sector in Vietnam (Decision No. 794/QD-BNN-TCTL) with the mission and goals focused on improving efficiency of water resources sector serving for target of restructuring agricultural sector (Decision No. 899/QD-TTg) towards higher added value and sustainable development is asking for concrete actions in research and practical application.

Vietnam northern mountainous region with characteristics of topography, climate and soil has great potential in the agricultural exploitation of the land on hilly slopes. However, this potential has not been exploited yet accordingly due to both technical and managerial reasons. Water for crops has always been considered the decisive factor for the success of agricultural production. Thus, issues on use of water sources from irrigation systems in the area need to be paid attention.
Small irrigation schemes in the northern mountainous region with similar investment of those in other areas in Vietnam but their performances are not high. These irrigation schemes only were designed to irrigate traditional farming areas, which are mostly flat land for rice cultivation. Hilly land areas around the reservoir with potential for development of high-value fruit trees, industrial trees have not been paid attention to invest into water supply manipulations. The main cause of ineffective exploitation of the schemes in these areas is the lack of scientific and technical solutions in water resources exploitation as well as nonconformities during cultivation.

There have been models applying on-farm water management solution, however, the performance of these models has not been evaluated. This research topic “Improvement of on-farm management for effective use of water resource from small- and medium-scale irrigation schemes in northern mountainous areas in Red River basin” will focus on analyzing measures that facilitate efficiency of water resources use as well as identify factors hindering or shortcoming during implementation process.

**Literature review**

Irrigated agriculture had been developed at a faster pace in the twentieth century. In 1900, irrigated area of the world was of 40 million hectares, reached 96 million hectares by 1950, 2.4-fold increase. From 1950 to 1970 is rapid growth period: In 1970 amounted to 235 million hectares, an increase of nearly 7 million hectares per year. The next year, the pace slowed down: period 1970 - 1980, an average annual increase of 3 million hectares, raising the total irrigated area in 1980 to 265 million hectares. From 1980 to 1987, the average growth rate was only 2.3 million hectares per year (Geist, H., 2006). The main reason is due to the easily exploitable land areas were running out. It was needed to explore disadvantaged areas with limited water resources resulting into increasing investor interest. However, according to many experts, the development potential in irrigation of the world is still much. Yet, it is more important to implement synchronized and effective measures to well exploit irrigated areas, to develop irrigated agriculture sustainably.
According to FAO, in order to meet the challenges in the future, investment in agriculture must be reconsidered and overall strategy should be developed including research, promotion of agricultural production, capacity building for water users and promotion of global trade.

On-farm water management improvement has not been new in the world and it is considered as a frequent challenge for any irrigated agricultural sector (P. Wolff and T.-M. Stein, 2003). The problems in on-farm water management reported include both technical shortcoming and improper organization/institution, which resulting in inefficient use of water, into reducing total effectively irrigated area and leading to reduction of agricultural production.

In this context, the challenges impact on OFWM efforts include: increase of water demand of economic sectors push pressure on water for agriculture; world population explosion affecting food security, increasing pressure on agriculture; increasing influence of non-agricultural factors, e.g. urbanization process, for land use decisions of people; shifting in labor structure, i.e. decrease of labor in the agricultural sector, affecting farmers’ farming skill; limited capital for investment in irrigation works; permanently shifting agricultural structure; information for farmers; the orientation of the state that affects OFWM.

One of the important measures to enhance economic efficiency in watering crops is selection and application of appropriate irrigation methods and techniques since on-farm irrigation techniques play an important role in supplying and distributing water directly to the plant and determining the amount of on-farm water losses more or less. With usual irrigation methods and techniques watering, the water loss is very large. Efficient use of water has become an important factor in agricultural production in arid and semi-arid regions in the world. For solutions to reduce amount of on-farm water, the research results in the country and abroad showed that the application of water-saving irrigation procedure brings huge efficiency: amount of on-farm water can saved from 20 to 50%, while crop yields do not only decrease, but also tend to rise if the irrigation process is applied consistently (Hung, T. 2014). An integrated solution including solutions to moisturize, protect soil and water-saving irrigation
techniques is proposed to study in the research for effective use of on-farm water.

Soil protection measures are measures to make soil not change both in quality and quantity. These measures protect the soil from being washed away, being eroded, being contaminated, decreasing the nutrient contents in the soil and do not make degradation of soil.

Moisturizing measures as measures to retain water in the soil, i.e. reduce amount of evaporation, increase water holding capacity and can supplement moisture in soil.

Water-saving irrigation techniques - Localized irrigation system or low volume irrigation system - is characterized by regular supply of limited amount of water to be controlled to irrigate a part of farmland layer - effective function area of roots - for optimal use of water. Water-saving irrigation technique is the technique to supply the right amount of water to need of crops, no excess water, as well as no water losses during irrigation process. Besides, water-saving irrigation also contribute significantly into saving labor, fertilizer, active in pest control, which leads to positive environmental protection impacts in agricultural production. Israel, the world's leading countries for research, manufacturing, application and export of water-saving irrigation technology in the world, has an area of over 20,000 km², of which 20% of area has capability for agricultural production, the remaining areas are mainly plateaus and rocky mountains, droughts and water scarcity.
Along with the technical improvement, promoting involvement of farmers in water management will be the factor affecting sustainability of irrigated agriculture since they are the direct water users. They well understand the irrigation system and recognize by themselves what the problems should be solved and what should be adjusted during the management and operation process. Irrigation management transfer is one of the definitions in participatory irrigation management toward agricultural development based on relationship with other natural resources.

In Vietnam, as a solution to cope with water scarcity and drought, on-farm water management efforts were studied. The solutions in water harvesting, soil moisturizing, water-saving irrigation combined with community training on water-saving use, protecting soil and water in research topics of Tuan, LT (2010) confirmed that, on-farm water management improvement is the effective measure in strengthening the soil - water relationship, contributing to limit the influence of water scarcity for agriculture. Also the research, some of the crops and appropriate irrigation regime was proposed to apply in water shortage areas as a way to more rational use of water resources and ensure income from agriculture.

Studies of the solutions using water for crops on hill lands including tea, orange, grapefruit, medicinal plants have also been conducted by many Vietnamese scientists and it is confirmed that the hill land areas with high economic potential should be exploited though investment of efficient irrigation solutions, advanced farming techniques (Hung, T., 2014; Tuan, D. D., 2013)
Methodology

Desk study

In order to get an overview on the performance of irrigation head-works in form of small and medium reservoirs in the mountainous region and how water sources is used from these head-works, an intensive desk study will be conducted. Through the desk study which will be carried out at the same time with all phases of field study, the fellow can understand, cross check and interpret the findings.

Secondary data gathered from both published and unpublished documents and studies is as the main tool to conduct analysis and assessment.

Research relating to on-farm water management will supplement and help fellow to clarify concepts are identified in term of international level as well as in study area level. In addition, shortcomings between theory and practices will be identified by the fellow during desk study process in comparison with practical application in case study.

The fellow will selectively inherit stored data from the statistics of the management unit, local statistics. This is one of the most traditional and basic methods are often applied to investigate and assess the operational status of the irrigation works.

Case study methodology

Data were drawn from the cases study will be the factual basis to help answer identified research questions. The case study methodology will be conducted through the methods described in sub-sections below.

Data collection

The methods applied to develop the research are described figure 1: Interview
The meeting will be conducted with officials of Department of Agriculture and Rural Development (DARD) and Irrigation Management Company (IMC), officials from commune people’s committee, and farmers who directly involve in water use for agriculture. Participation of female in the interview is required to ensure that the opinions of interviewees are diversified and can cover all concerned issues. The results from the in-depth interview are to find out knowledge of local officials and people as well as their opinions on current water efficiency and improvement of On-farm Water Management (OFWM).

**Survey and observation**

Observation helps observers to have firsthand look and better understanding of the context; to verify data, and provide typical information relating to the situation. This method also supports to re-examine and help to understand better condition, performance of the system that other methods cannot give reliable results. The timing selected to perform field observation will be the time when
the system is operating at normal conditions, for instance, when the water is being supplied for crops.

**Conceptual framework**

**Water management:**

Water management is the activity of planning, developing, allocating and using water optimally in accordance with identified objectives. Both quantity and quality of the water resources shall be included in these activities. Method of modern water management is conducted based on the hydraulic unit. In order to work effectively, irrigation systems need to be managed as hydraulic system spreading from head-works to the intakes, to the end of canal or to drainage canal, and are not be dispersed due to administrative boundaries. During the process, human controls concretely with interventions concerning all surface and sub-surface water. All activities of water planning, development, distribution and use are seen as a stage of water cycle management. Ideally, water management has regard to all demands for water, even competing, and plans to allocate water on a proper basis to satisfy all uses and demands.

**On-farm water management:**

OFWM is defined as a manner to use water within boundary of a private farm, a farming plot of private farmers or farmer groups from a small irrigation system, or within scope of a field of farmer group/organization sharing water from a medium or large irrigation system. Performance of OFWM is to optimize water – plant relationship to achieve desired yield and quality, resulting into optimization of profits. Thus, water has to be managed skillfully through use of practices and tools for all irrigated area, including: harmonizing water – soil – plant relationship, soil reclamation and improvement, drainage, farming manipulations. Moreover, it also includes use of practices and tools to improve site conditions and to protect plants and farming facilities from excessive water (Izuno, 1997).
The key-driven factors affecting the performance of OFWM are both technical and institutional/organizational factors. Identified problems in OFWM are:

- Technical:
  - Farm level irrigation system;
  - Water – plant relationship (crops water requirement, crops object)
  - Economic efficiency in water use and crop object;

- Organization/institution:
  - Irrigation management organization;
  - Farmers’ knowledge (crops water requirement and new technologies).

### Results and analysis

**Characteristics of irrigation systems in mountainous region**

Irrigation systems in mountainous regions have different characteristics than other areas of Vietnam by what's unique about terrain and water conditions (Hieu, 2011). These characteristics may include:

- They are almost small-scale hydraulic works with forms of head-works as reservoirs, weirs or gravity intakes to serve for cultivated areas with different scales;

- Because of complex terrain conditions, fragmented, dispersed cultivated areas, thus, irrigation systems are often small and scattered, far from residential areas. It is difficult for management, maintenance of irrigation systems and high cost;

- Number of the irrigation systems is very little compared to the production requirements, mostly serve for rice cultivation, few areas of upland crops and cash crop. Hydraulic works for fruit trees and
industrial trees have not been invested. Irrigation systems can only serve for 30% - 40% of agricultural land and reach 50% - 70% of the design capacity.

- Due to the complex terrain, difficult to mobilize labor and machinery, as well as difficult construction conditions, investment rates is high - 2-3 times higher than construction cost in the delta (Hieu, 2011).

- The temporary works are very popular, with large numbers, mainly constructed by local people to take advantage of seasonal irrigation water.

- Except for the areas located along rivers and streams, with guaranteed irrigation water source, while most of the remaining cultivated areas are lack of water for irrigation since it depends on rain water. Water source of irrigation systems may come from small reservoirs, streams of water from the weirs or underground water stemming from the foothills.

**Traditional perspective of farming on slopes**

Vietnam is known as the country with three-quarters of the land is hilly, mostly sloping land. In which, the areas with slope over 25% making up 50% of the total sloping land (Figure 2). Although there is a large area and the unique advantage of the natural conditions for the production of specialty crops with high economic value, this kind of land is difficult to exploit and use. Due to lack of productive land, farmers in mountainous region have cultivated on soils with slope greater than 10° which is highly eroded and cultivation period is shortened. The farmers can cultivate in 1-2 seasons of short-term food crops or cassava and be deserted (Doanh, 2006). Cultivation mode mainly depends on rain and therefore there is greater risk for agricultural production and people's lives. Agricultural production on sloping land is mostly characterized by fully exploit land and natural resources, self-supply, unstable and unsustainable.
Relations between the slope of the ground and irrigation methods

Because of the complex mountainous terrain, irregular rainfall, large amount of evaporation, strong permeability soils, low flow coefficient, uneven and scattered cultivation areas, the water resources is very limited and it is difficult to allocate water resources and arrangement of on-farm irrigation systems.

Slope relates to selection of irrigation methods and techniques. Flow irrigation techniques such as furrow irrigation, earth ditch irrigation in steep slope terrain are unsuitable, but sprinklers and drip irrigation is possible to apply. In case of large ground slope, it should not use large irrigation level because it may cause erosion and uneven distribution of moisture.
Table 1: Relation between ground slope and irrigation methods

<table>
<thead>
<tr>
<th>Slope (i)</th>
<th>Furrow irrigation</th>
<th>Furrow irrigation with portable pipeline</th>
<th>Sprinkler, drip irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 0.015</td>
<td>Applicable</td>
<td>Applicable</td>
<td>Applicable</td>
</tr>
<tr>
<td>0.015 – 0.01</td>
<td>Inapplicable</td>
<td>Applicable</td>
<td>Applicable</td>
</tr>
<tr>
<td>&gt;0.01</td>
<td>Inapplicable</td>
<td>Inapplicable</td>
<td>Applicable</td>
</tr>
</tbody>
</table>

*Source: Khang & Anh, 2009*

Collecting and storing water at site combined with drip irrigation - a sustainable development solution to increase value of oranges cultivation on slopes in Hoa Binh province

Cao Phong Town, Cao Phong district, Hoa Binh province is well known with famous brand of Cao Phong oranges, depicted geographical indications. Located on an average altitude of 399m above the sea level with a strongly divided terrain, average terrain slope of 10-15%, geological conditions are favorable for orange cultivation but water holding capacity of soil is poor.

Water sources to irrigate 1,200 hectares of oranges in the town relies on water from Dac Tra reservoir and some natural streams in the area when the irrigation demand has exceeded the capacity of Dak Tra reservoir. On-farm irrigation systems mostly use pipes and pumps from the reservoir to supply water with high cost of investment and 1-2km of distance by farmers. Common irrigation measures for orange now are providing water to the trees by pipes manually and high pressure sprinklers. These two irrigation solutions not only waste water but also require more labor to water, low ability to proactively provide water for trees, causing land erosion and loss of fertilizer, affecting to productivity and quality of oranges.

To overcome these limitations while taking advantage of resources in a reasonable manner, the rainwater harvesting solutions at site have been applied.
Figure 3: Layout of water collection and storage system at site

![Layout of water collection and storage system](image)

*Source: Thao, 2016*

Figure 4: Drip irrigation technique for Orange tree in Cao Phong district *(Source: Thao, 2016)*

![Drip irrigation technique](image)

*Source: Thao, 2016*

The basic principle of the technology is to take advantage of topology of hilly lands to avoid soil erosion by water collecting ditch systems arranged by contourlines in the garden, to build rainwater collection tanks for initiative irrigation at site and gravity fed irrigation for each orange tree.
To supply water to orange trees, drip irrigation system has been used. The basic principle of the system is via the central control system and pressurized water sprinklers, water is supplied to every trees with the same flow, not affected by slope. Users can fully control amount of water to the orange tree from a few liters per tree to thousands liters per tree in one time of irrigation. At the same time, through the irrigation systems, fertilizer and plant protection products can be injected which supports to manage nutrition proactively and efficiently for orange tree.

Mr. Ly Dinh Hung, a farmer in Zone 7, Cao Phong town, was very satisfied after one year applied drip irrigation system for 2.5 ha of oranges and constructed one water collection storage tank of 80 m³, he quoted that:

“Previously, it cost much every time I watered the orange because of pumping costs. It was most difficult to bring pipeline to every trees for irrigating, so that I could not manage time to water frequently. It was the same with fertilizing, I can only wait until it rains to give fertilizer to each tree. Many times, after fertilizing, it did not rain, manure was melted and it wasted and it could not be absorbed by plants. Now, I mix fertilizer in tank with water and just switch on the pump. Done! Only about 2 hours, the whole gardens is irrigated. The amount of water to every plants is all the same.”

Figure 5: Scattered rice area, not provided enough water from Te Le reservoir (Source: Thao P. T. P., 2016)
Shifting crop structures to effectively use scarce water sources in Phu Tho province

Te Le reservoir located in Te Le commune, Tam Nong district, Phu Tho province was upgraded in 2012 with a total investment of about 10 billion VND (approximately USD 500,000) from fund of the province, in order to irrigate 4 hectare of rice land area (see irrigated area in figure 5). Although it has been upgraded and rehabilitated to improve lower water level situation during dry seasons, it fails to provide water for rice cultivation area as designed. Thus, the reservoir had not been exploited and used effectively.

In the meantime, there are 20 hectares of planting forestry area surrounding the reservoir with low economic value trees, such as acacia, eucalyptus. Realizing the potential of water extraction from the reservoir for agriculture on slopes, local authorities have coordinated with an enterprise that processes medicinal plants to re-structure the agricultural production for the areas around the reservoir and have improved water use efficiency.

First of all, the 20 hectare of land around the reservoir was allocated to the enterprise to transform from forestry to medicinal plants with higher economic value and shorter harvesting time. Irrigation systems serving medicinal plants were redesigned with criteria to use efficiently water and land resources, avoid waste and reduce soil erosion.

Figure 6: Layout of the irrigated areas using advanced irrigation techniques (Source: Thao P. T. P., 2016)
Water used for irrigation from Te Le reservoir, located about 400m from the irrigated area, is pumped to a water storage pond at the irrigated area with volume of about 400m³. From the water storage pond, a water-saving irrigation system combined with fertilizing is installed to carry water and fertilizers directly to every tree root (illustration of the system is in figure 6). The control of fertilizers and irrigation water helps to limit the excessive use of fertilizers causing soil pollution as well as water runoff causing soil erosion and hardening the surface. In addition, because the required amount of water for upland crops is less than that of water needed for rice cultivation, Te Le reservoir is fully able to irrigate 20ha area of upland crops, instead of being not enough water for 4ha of rice as before. In addition, the economic value of the upland crops such as pineapple, sesame, medicinal herbs is much higher than that of rice. Economic efficiency of agricultural production has increased due to restructuring of the plant, utilizing sloping land and application of reasonable irrigation techniques, improving income people in the region.

Currently, the local authorities and community are very satisfied with the conversion of the plant as well as the application of small irrigation measures in the region and plans to expand this model to other locations with similar conditions in the commune.
Conclusion and recommendation

The potential of a large part of hilly land in Vietnam is not currently exploited to develop specialty crops due to limitations of both investment and technology applying. Thanks to advantage of sloping land area such as large rainfall, seasonal distribution water is favorable to be collected. In other hands, application of drip irrigation system helps to prevent soil erosion, save water and control fertilizer for orange in Cao Phong. Result from combination of the technology indicates this is a new direction in approaching irrigation solutions for agricultural production in sloping land. The results have confirmed that the application of these solutions not only effectively help to solve water scarcity problem but also is a new cultivation solution to help reduce production costs, increase productivity and quality in terms of nutrition composition and aesthetic of Cao Phong orange products.

Hilly land in Vietnam, accounting for over three quarters of the natural land area, is the resource with great potential in agricultural production. The efficient, sustainable management and use of sloping land will determine the development of agriculture and forestry in the near future. Besides agricultural techniques, applying advance irrigation and water storage techniques is considered as efficient measures to support sustainable production, soil conservation and erosion control for cultivation on slopes. Small-scale irrigation in combination with the restructure of plantation can be applied easily in the sloping farming areas have irrigation systems but inefficiently operated. It can also be applied for various plants.
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