Water resources institutions and Technical efficiency by smallholder farmers: A case study from Cuatro Lagunas, Peru

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Summary

Cuatro Lagunas, located in the Peruvian rural highlands, is a rural territory with strong cultural and social identity where economic and institutional factors interact over the natural resources allocation. This traditional poor area, traditionally governed by communal institutions, has shown a dynamic pattern of economic growth during the last fifteen years. However, the economic growth has come together with more intensive use and contested situations over the natural resources in the territory. In this scenario, the purpose of this research is to assess the interaction between the institutions governing natural resources use and the economic performance by smallholder farmers. In particular, the study aim is to analyze how the increasing demand for water resources in the territory has led to changes in its institutional structure that ultimately affect agricultural productivity by farmers.

This study presents evidence that Cuatro lagunas is changing its institutional framework and giving room to more autonomous institutions and more presence of the State law allocating water resources. In Cuatro Lagunas this study finds the coexistence of different institutional regimes governing water allocation. There are institutions allocating resource under the national legal framework and under the customary law. Furthermore, under the customary law there are independent and centralized regimes. The economic dynamism in this territory is giving more presence to independent regimes and more presence of institutions governed by the Water Resources law. In contexts of increased water demand and contested situations over common pool water resources the water rights by the State are considered more secure title to assure mutual acknowledgement between communities that share the resources. Finally, the empirical analysis shows the significant association between higher levels of technical efficiency and the participation in more independent institutional regimes allocating water resources.

1.- Introduction

The relevant literature about rural poverty has documented the existence of institutional failures that prevent access to markets (Trivelli et al. 2009, Escobal et al. 1998) and affect economic efficiency and profitability by smallholder farmers (Escobal, 2006). In this vein, the role of institutions on natural resources allocation is especially crucial, considering that rural households' dependence on those resources is high. Natural capital plays a key role for the profitability of economic activities by determining investment decisions and productivity outcomes (Carney 1998, Lee and Neves 2010).

The institutional scenario to access natural resources affects efficiency on allocation and ultimately farmers´ productivity and returns. In this vein, the presence of high transaction costs may discourage poorer farmers from using irrigation and may affect the efficiency on allocation (Zegarra 2002a, Zegarra 2004). Furthermore, the lack of market mechanisms1 and the complexity of institutions governing water allocation have been documented by the literature as institutional barriers affecting access to irrigation. Among the most relevant institutional barriers, the existence of legal dualities, are relevant factors driving water resources conflicts by users and affecting natural resources allocation (Trawick 2003, Bruns and Meinzen-Dick, 2000).

The literature on irrigation institutions in the Andean countries, has documented several of these conflicts and complexities on water resources use by Andean and indigenous communities (Boelens and Hoogendam 2002, Boelens, 2009, Sosa 2008, Verzijl 2005). This is especially the case when there are difficulties to implement a national legal system over cultural and geographical diverse territories. The Andean countries involve a cultural diversity that imposes a singular complexity for the institutions governing collective use of water resources (Boelens 2009).

The topic of Peruvian highlands' irrigation is an interesting field of research. In Peru, the highlands' agricultural fields were traditionally rainfed but now are increasing the use of surface water to complement rainfall availability throughout the year. There are studies that documented the positive impacts of irrigation on agricultural performance by Peruvian farmers (Datar and Del Carpio 2009, Baca 1998). Irrigation availability in the highlands provides more agricultural production and more opportunities to access markets (Baca 1998). However, the role of irrigation institutions in farmers' productivity has not been studied with great detail yet. In the Peruvian highlands water markets are non-

[1] Zegarra (2002b) documented the importance of market mechanisms to achieve efficient allocation of water resources.

existent and resources are allocated by several types of institutional regimes generating a complex scenario for the allocation of the resource (Trawick 2003, Bruns and Meinzen-Dick, 2000, Boelens 2009, De Vos 2006).

During the last years, one of the government's reactions to increased demands and needs for irrigation in the highlands has been the increase of irrigation infrastructure provision in the Sierra region, sponsored by international funding support (PSI Sierra Project, Meriss Inka Project). However, the improved irrigation infrastructure itself does not guarantee efficient and equitable access to irrigation. Thus, there is much room for the provision of institutional support to allocate water resources more efficiently together with more technical support to enhance farmers' capabilities on the use and maintenance of the infrastructure provided.

The Peruvian government has recently launched a legal reform on water resources management at the national level, involving all economic sectors and users. This reform has brought a new administrative and political system for water resources management with a basin level approach (ANA 2009a). In this context, the new legal framework provides a relevant scope for policies aimed at supporting water resources governance by small scale famers. However, it is still challenged by the socioeconomic and geographical diversity of territories in Peru and the coexistence of communal institutions traditionally governing natural resources allocation in the rural communities.

The case study of Cuatro Lagunas is especially interesting. This is a very traditional poor area, located in the Peruvian rural highlands, that has shown a dynamic pattern of economic growth during the last fifteen years. However, this economic growth has come together with more intensive use and contested situations over the natural resources in the territory (Escobal and Ponce 2010). In particular, the territory has increased its demand and conflicts over the existing water resources to sustain agricultural and other economic activities. In this context, the analysis of the institutional complexities on water resources allocation would be relevant to contribute policies aimed at providing legal and institutional support to enhance farmers´ capabilities on water resources sustainable management, productivity and consequently, income.

Furthermore, the assessment of irrigation institutions in this territory constitutes a relevant topic for research, particularly on the strand of rural territorial development. The area of Cuatro Lagunas is a rural territory with social and cultural identity (RIMISP 2009) where economic and institutional factors strongly interact over the natural resources allocation. This interaction creates an interesting scenario to assess the key role by economic institutions affecting natural resources allocation and consequently economic growth.

The objectives of this research are twofold: First, to present an overview of the current state of irrigation institutions in the Cuatro Lagunas´ territory and, based on that, the second objective is to analyze the relationship between these irrigation institutions and the technical efficiency by small-scale farmers.

Research Questions

Given these objectives, the purpose of this research is to answer the following questions:

1. How is the current state of water allocation by small-scale farmers in Cuatro Lagunas? Which institutional framework governs water resources allocation across the territory? Does the current allocation system vary between villages in the territory?

2. What is the role of these institutions allocating water resources in the technical efficiency levels by small-scale farmers?

To answer these research questions, this study combines applied and theoretical approaches. For the first part of the analysis, a theoretical and legal approach will be used to assess the institutional framework beyond current water resources allocation. For the second part, a parametrical stochastic model will be estimated in order to analyse the technical efficiency of small-scale farmers in the territory. The model is intended to capture the effects associated with the institutional regime regarding water allocation and farmers' individual productive outcomes.

The information used for this research is based on primary and secondary data gathered from several agencies and actors in the territory. For the first part of the analysis a set of semi-structured interviews conducted to key agents in the territory[2] during December 2010 and January 2011 will be used. The information from these interviews will be complemented by secondary data gathered from the National Water Authority and the SENAMHI[3], used to describe the legal and hydrological context of Cuatro Lagunas. For the second part of the analysis, a household survey data, DTR survey[4], collected by GRADE from small-scale farmers in 2009 will be used and complemented with information from the first part of the document.

2 The interviews were conducted in Cuatro Lagunas to irrigation committees' authorities and users, local authorities and government officials.
3 SENAMHI is the National Service of Meteorology and Hydrology of Peru.
4 Rural Territorial Dynamics Survey (Encuesta sobre Desarrollo Territorial Rural, DTR) in Cuatro Lagunas, Cusco. 2009

The structure of this paper is the following. In section 2 a conceptual discussion will address the economic management of water resources and the institutions that govern water resource allocation. Section three presents a description of the study area. Section four presents the current state of the water allocation for agriculture. This chapter will present the institutional, legal and economic aspects beyond the current water allocation system in the territory. Section five will present the empirical estimation of the role by irrigation institutions on technical efficiency. Section six concludes the paper.

2.- Conceptual framework and literature review

2.1. Natural capital and property rights

Natural capital plays a key role as factor influencing the profitability of economic activities in rural areas. It has been incorporated by the literature about rural sustainable livelihoods, adding up, as one of the five forms of capital on which households base their consumption and production decisions. Thus, natural capital is considered productive capital as it is the human capital, physical capital, social capital and financial capital (Carney 1998, Lee and Neves 2010) and constitutes crucial productive asset that influence economic decisions as well as productivity outcomes by smallholder farmers.

Elements of the natural capital such as soil, water, forests, fish and wildlife support daily economic activities by rural households but are subject to excessive use, free riding and other negative externalities affecting its efficient allocation. The allocation of this type of capital is subject to contested situations due to institutional complexities on definition and delimitation of the services provided by the resources. In this vein, there is no consensus on whether natural resources can be private or public capital. From the literature on natural resources, the natural capital is a public good (non-excludable) but has features of private goods (its consumption might be rivalrous), meaning that its use by one individual reduces the ability by others to use it.

The academic literature about environmental resources has documented the institutional arrangements that lead to the efficient and sustainable use of natural resources. According to the economic theory a resource is efficiently used if it has been allocated to their highest value in use, based on the marginal willingness to pay (Perman et al, 2011). Thus, an inefficient use of natural resources would take place whenever any adverse outcome affects a production function, or utility function, preventing resources from being allocated to their highest value in use. (Grafton et al. 2004).

Property rights play an important role to achieve efficient allocation of natural resources. They are the secure set of claims and entitlements, but also obligations, to any resource or any service that a resource provides (Furubotn and Pejovich, 1992). It exists over a resource whenever the right is acknowledged, legitimized and enforced by any institution (Ostrom 1990) and it is possible to exclude others from using it.

In rural areas natural resources are managed as common pool resources. In this context, resources can be allocated under open access or under common property rights. Open access is a regime where there are no rules governing the allocation of the resource. It is a free-for-all regime. On the other hand, common property rights are special class of property rights. Common property rights define a particular bundle of rights and obligations for community members and assure individual access over common pool resources in which collective claims take place (Gibbs and Bromley 1989).

The literature has documented how the open access or absence of property rights can lead to undesired outcomes such as lack of incentives to invest or overuse the resource. Hardin (1968) documented the concept of the "tragedy of the commons" to explain how the lack of defined property rights (open access) may lead to adverse outcomes such as over-exploitation and free riding of common pool natural resources. Under open access regime, a private farmer lacks the economic incentives to improve resource use or make investments, because others will benefit from such private investments without any payment (Lee and Neves 2010).

2.2. Surface water resources

For the purpose of this study, the analysis will be focused only on surface water resources[5]. Surface water provides consumption services from water resources in rivers, lakes, springs (or a share of a water reservoir), that are naturally replenished by precipitation but also lost through discharge to evaporation. Surface water can renew its quantities every rainy season but it can also be scarce during dry seasons.

Irrigation for agriculture is one of the biggest users of surface water. It is a process that conveys water from a common pool resource to a particular property. The allocation of irrigation water is affected by the nature of water resources. Among the most crucial features are: randomness, imperfect divisibility, mobility and rivalry. (Zegarra 2002b).

Randomness: The quantities of surface running off are randomly determined. It depends on environmental conditions.

Mobility: water is a mobile resource, it tends to flow, evaporate and transpire. It runs off over transboundary limits.

Imperfect divisibility: Water flows can seldom be divided into discrete units for individual use. Irrigation water is an imperfect excludable resource; it needs

[5] Water resources involve surface water, groundwater and rainfall.

special devises for volumetric measurement and division that sometimes result unaffordable for rural communities in the rural highlands.

Rivalry: Irrigation systems have a maximum capacity of flow and it can get congested at some point in time during the year. In the peak season, water is demanded as a rival good because the consumption by one user can reduce other's consumption (Ansink and Weikard 2009).

In addition to these features that affect the allocation of water resources, irrigation water will demand a combination of skills on hydraulic infrastructure use as well as on managerial decisions. These managerial decisions have to do with the institutional arrangements defining relationships among water users from a specific common pool water source. Furthermore, the institutional arrangements should be respected and accepted by the institution and its members. It will govern rights to water, irrigated land use and labor relations for cleaning and maintaining hydraulic infrastructure. In absence of well-defined institutions the water flows can be wasted, stolen or overdrawn. Thus, the presence of well-defined institutions, are key elements for the efficient and sustainable use of natural resource.

2.3. Irrigation institutions

Policy strategies aimed at improving irrigation for smallholding agriculture can contribute to enhance productivity and profitability of agricultural activities (Gebregziabher et al 2009; Datar and Del Carpio 2009; Smith, 2004). Irrigation is a key asset for agriculture. It not only provides for more water availability but it contributes to stabilize crop patterns, minimize risk exposure and access to more profitable markets (Datar and Del Carpio 2009). The increase in water availability allows for the increase of agricultural production (Baca 1998), and more crop intensity (allowing more than one cropping season).

Irrigation is defined as the artificial application of water to land, particularly for agricultural purposes. It contributes to enhance water availability for farming activities and consequently farmer's productivity. Irrigation is a key asset for agriculture because it contributes to stabilize crop patterns, reduces risk exposure and support access to more profitable markets (Datar and Del Carpio 2009, Dorward et al. 2002). The increase in water availability allows for the increase of agricultural production (Baca 1998), and more crop intensity (allowing more than one cropping season).

Ostrom (1990) defined irrigation institutions as "The set of working rules for supplying and using irrigation water in a particular location" Working rules in irrigation institutions are used to determine decision over actions allowed and constrained, information provided and constrained as well as costs and payoffs assigned to individuals as a result of their actions.

Antother relevant concept for irrigation institutions can be derived from the property rights definition: the concept of water rights. Nonetheless in this case, water rights do not necessarily entitle ownership of the resource but ownership of the services provided by the resource. Hoogendam (1995), defined water rights as the set of authorized claims to benefits, as well as obligations, on the services associated to water resources.

Following Shlager and Ostrom (1992), we can represent water rights for irrigation as a "bundle of rights" divided in two groups: The rights to access and the rights to take part in the managerial decisions. The first group involves rights to access the irrigation system and withdrawal of the water source. The second group involves right management (or governance), exclusion and alienation. See table 1.

Table 1: Bundle of rights for irrigation

Type of right	Description
Access:	The right to access the irrigation system and the physical infrastructure. It also imply the membership in the irrigation institution
Withdrawal:	The right to extract water for irrigation
Management:	The right to take part in decisions regarding use, allocation, distribution, improvements and transformation over the common pool water source
Exclusion:	The right to determine who is eligible for the rights.
Alienation:	How the rights can be transferred. The right to sell or lease, either or both.

Source: Adapted from Schlager and Ostrom (1992)

Barriers for the access are factors driving inefficiencies in the allocation. The uneven provision of irrigation infrastructure and transaction costs, or other institutional barriers, at the initial stage prevents farmers from entering to the irrigation system. Barriers for the access can have adverse distributional effects, especially for the less endowed.

The right to withdraw the resource assures the right to use a certain amount of water conveyed to a particular land plot for irrigation. Secure rights to withdraw water impacts positively in the planning of production and sowing activities. It is important to mention, however, that water withdrawal is subject to internal regulations regarding water use turns, unit measurement for water and infrastructure to convey it as well as water fees.

Management rights are associated to the capacity to take part of the managerial decisions regarding implementation of water allocation, distribution, as well as water fees. These types of decisions are taken under the general assembly of members of the water user association, where members have the right to vote.

Decisions regarding alienation and exclusion can also be taken with the approval by the general assembly of members of the water user association. The right to take part in these decisions enables members to incorporate their interests and concerns in the decision implemented.

2.4 Water rights acquisition

The literature on irrigation institutions points out the existence of two types of institutional water right acquisition frameworks that acknowledge and enforce water resources property rights: legal ownership and customary laws. Legal ownership involves a state system, in which access is owned by State and is governed *de jure* by central legal and administrative authorities. On the other hand, the customary system, governs *de facto* and its rules are based on customary laws, historic and traditional rules and arrangements that are the part of a collective ownership (Cotula, 2006). This is particularly important in areas such as the Peruvian rural highlands with a considerable presence of rural communities and traditions and cultural rules governing access, allocation and use of resources. Customary rights of water users associations may originate from community norms, religious values and historic practices which often encounter conflicts with the state "privatized" rights to water use (Bruns and Meinzen-Dick, 2000).

Boelens (1999) distinguishes five types of mechanisms to obtain water rights, considering the customary and traditional framework governing water allocation by Andean communities (Table 2). The concessions, licenses and permits are the most closely related to the legal ownership of acquisition; however, the property in this case still remains on the side of the owner. The other types of acquisition are relevant for rural communities in the Peruvian highlands. Transfer of rights generally occurs when rights are tied to the land and the land is sold or transferred to another farmer. The most common mechanisms for water acquisition for the Peruvian highlands are the historical and the socio territorial.

Table 2: Mechanisms of water rights acquisition

Concession/License/Permit	Ownership remains in the hand of the owner.
Transfer	The *transfer* of water rights from one right holder to another trough sale, inheritance, marriage, exchange or donations.
Historical /	Imply a "first come claim principle".
Socio-territorial	Inhabitants of the region to which the water source is connected, claim this water under the territorial principle

Source: Adapted from Boelens (2009)

Water rights for irrigation are also tied to a bundle of obligations set up to contribute to the sustainability and the functioning of the irrigation system. The bundle of obligations is associated to monetary and/or non-monetary contribution together with the participation in activities promoted by the association. The monetary contribution is the water fee, established by the general assembly of users. The non monetary contribution has to do with labor supplied for the cleaning and maintenance activities of the hydraulic infrastructure. Furthermore, other obligations established by the irrigation institution involve compulsory participation in the institutional activities of every general assembly (sometimes the non attendance is penalized with a fine), and the availability to become part of the board of directives “ad honorem” by election or by turns.

The analysis of the conceptual framework presented here will be presented in sections four and five. Section four will present a more detailed discussion about the institutions governing irrigation institutions in the area of study and section five will discuss the role of institutions on the technical efficiency by smallholder farmers.

3.- The area of study

3.1 Location

The territory of the study is Cuatro Lagunas, located in the southern highlands of Peru, in the department of Cusco. (See Map 1). This area includes six districts: Pomacanchi, Sangará, Acopia, Mosocllacta, Pampamarca, and Tupac Amaru, located within two provinces: Acomayo and Canas.

Table 3: Districts in the territory of Cuatro Lagunas

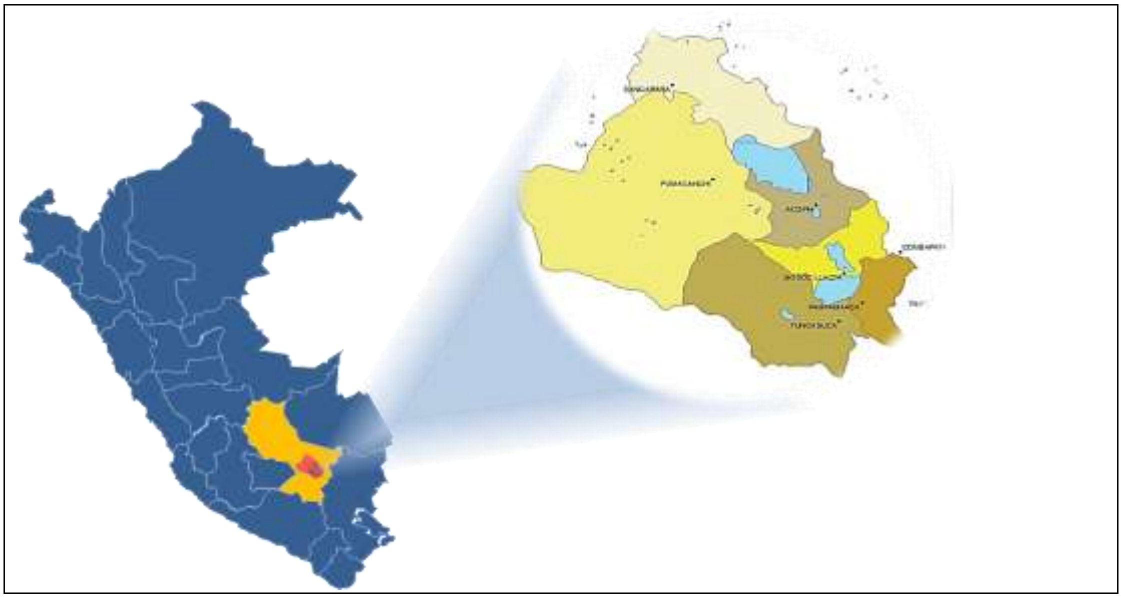
District	Province	Population 1 a/	Altitude (m.a.s.l.) 1/	Surface (km2) 2/	Number of rural communities 3/
Pomacanchi	Acomayo	8340	3679	274	12
Sangarara	Acomayo	3753	3763	83	4
Acopia	Acomayo	2557	3715	71	3
Mosoc Llacta	Acomayo	1864	3802	44	3
Pampamarca	Canas	2047	3811	31	3
Tupac Amaru	Canas	2965	3791	119	8

a/ National Census of Population and Dwellings 2007
Source: 1/ INEI 2/ANA 3/MINAG

The area of Cuatro Lagunas has a unique landscape, scattered with small lakes that surround the territory playing an important role for the well-tempered climate in the area. Given the territory's high altitude (on average 3,760 m.a.s.l.), the climate is moderated with little temperature variation compared to other areas with the same altitude. According to SENAMHI,[6] the annual average temperature reported for the last twenty-five years (1986-2011) in the SENAMHI weather station located in Pomacanchi is 10.5 ºC with a low variation coefficient of 0.047. The average monthly temperature ranges between 8.3 ºC and 12 °C.

[6] SENAMHI is the National Service of Meteorology and Hydrology of Peru.

Map 1: Peru and the territory of "Cuatro Lagunas" in Cusco



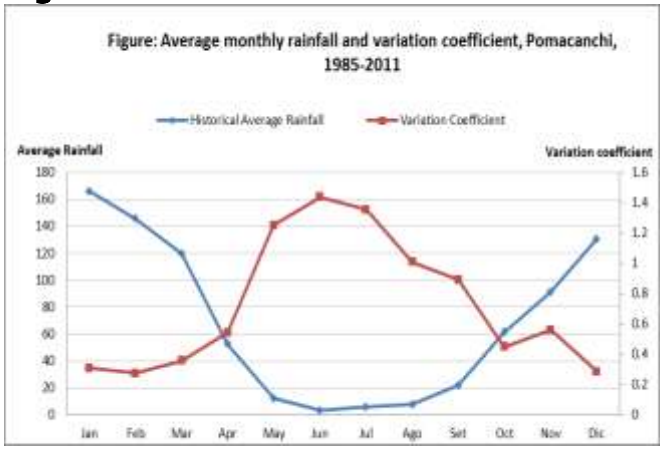
Source: INEI

3.2 Water resources in the territory

3.2.1 Runoff

Rainfall season in the highlands has a defined pattern that generates a hydrological deficit for specific months during the year. It starts approximately in October, lasts until March or April, and generally coincides with the main season for transitory cropping. Figure 1 presents the long term average monthly rainfall (1985–2011) and its variation coefficient, registered at the SENAMHI weather station in Pomacanchi. The average monthly rainfall during the rainy season can be as high as 110 millimeters and then drops to close to zero (10 millimeters) during the dry season. The dry season is the period with the highest variation. For the year overall, the average rainfall in Pomacanchi reaches a total of 703 millimeters.

Figure 1



Source: SENAMHI

3.2.2 Surface water resources

Across the territory, the varied geography defined by the presence of the Andes mountain range configures a drainage network of hydrographic units that are tributaries of two basins: the Urubamba-Vilcanota "Vilcanota" basin and the Pampas-Apurimac "Apurimac" basin. Both contain tributaries of the Amazon River (affluent of the Atlantic Ocean) and the Vilcanota basin contains one of the most important tributaries of this river: The Urubamba -Vilcanota river.

The hydrologic system that configures the surface water availability is determined by these two basins that divide the territory in two areas (See table 4 and map in Appendix). The Vilcanota basin comprises departments of Cusco and Ucayali and for the territory of Cuatro Lagunas it comprises 61.5 % of territorial surface and about 88% of its population. The other basin, Apurimac, encompasses territory of several regions: Apurimac, Ayacucho, Arequipa, Puno and a small part of the Cusco region. The area of Cuatro Lagunas under this basin, represents about 12% of its territory. ANA (2010a).

Table 4. Total Area and Population by District and Basin

District	Total Area	Population in Vilcanota Basin		Population in Apurimac Basin	
	Km2	Population	%	Population	%
Mosoc Llacta	43.78	1,864	100	0	0
Acopia	70.73	2,557	100	0	0
Pomacanchi	273.64	5,893	79.4	1,526	20.6
Sangarara	82.92	3,753	100		0
Pampamarca	31.39	2,047	100		0
Tupac Amaru	118.56	881	51.5	830	48.5
Total:	621.01	16,995	87.82	2,356	12.18

Source: ANA (2010a) and INEI

According to the National Water Authority, in the territory of study there are basically four types of surface water sources: streams, springs, lakes, and rivers. Lakes and rivers are the main water sources for agricultural uses in the territory, however there are considerable streams and springs which play important role for the water availability since these are main tributaries of lakes and rivers.

Surface water resources in the territory are used to sustain household consumption and economic activities. However, the geographical and topographical configuration of the hydrographic units in these two basins restricts the use of water resources. In the case of agriculture, land plots are located primarily in very steep inter-Andean valleys where gravity or sprinkler irrigation methods that are very difficult to implement. Pumping water is not an option in the territory due to expensive costs.

3.2.2.1 Lakes

The territory is endowed with a variety of springs and small lakes. Among the biggest and most important ones are: Pomacanchi, Pampamarca, Acopia, and Mosoc Llacta. All of them belong to the Vilcanota Basin. Pomacanchi is the biggest lake, and it borders three out of the six districts in the area (see Table 2). In terms of territorial extension, however, Pomacanchi is considered small lake with an area of 21 square km (INEI, 2011) and an average depth of 35 m. The deepest part of the lake reaches 100 m (PRODUCE, 2002).

Most of the lakes constitute natural water reservoirs for the territory with usable potential availability[7]; however, they are not used in all its potential. The

[7] One of the lakes, Mosoc Llacta, concentrates saline and mineral substances being and endorheic water mass and is not used for agricultural consumption.

lakes are mainly used for fisheries, one of the complementary economic activities by farmers. Pomacanchi, Pampamarca and Acopia provide freshwater resources, mostly mackerel and carp, which are only extracted by the villages surrounding the lakes. For the agriculture, which is still the one of the main income generation activity in the territory, these water resources are only used by downstream villages. This is due to the complex geography of the territory which would require the use of expensive equipment to pump water from the lake to the upstream areas.

Table 5: Main lakes in the territory

Name	Districts	Altitude (m.a.s.l) 1/	Water surface (Km2) 2/	Main uses	Main tributaries and effluents used for agriculture
Pomacanchi	Pomacanchi, Sangarará, Acopia	3660	21	Fishery/low use in agriculture	Huata river, tributary
Mosoc Llacta	Mosocllacta	3760	8	-	-
Pampamarca-Tungasuca	Pampamarca, Tupac Amaru	3785	3	Fishery/low use in agriculture	Jabonmayo river, tributary, Chacamayor river, effluent
Acopia	Acopia	3700	-	Fishery/low use in agriculture	Santo Domingo river, tributary

Source: 1/ ANA 2/INEI

The water from the lakes is replenished basically with rainfall and water runoff from upper springs located in the peak of the mountains. Two out of the four main lakes have implemented a system to regulate the water runoff. The lakes Pomacanchi and Pampamarca have implemented infrastructure to control the level of water stored in order to prevent floods on the offshore lands during the rainy season. The other reason for the water regulation in the lakes is to secure a reasonable flow of water in the lake during the dry season[8]. In both lakes, the regulation infrastructure was implemented by development projects funded by external institutions (PRODERM and IMA) from Cusco.

[8] The effluent rivers are used for irrigation: Cebadapata river, effluent from Pomacanchi lake and Chacamayo river, effluent from Pampamarca lake.

3.2.2.2 Rivers

Rivers are the main source for irrigation in Cuatro Lagunas. They are naturally replenished with glacial melt water flowing. During the months of December - February (rainy months) they get considerable high flows but during April –July (dry season) flows are reduced due to the absence of rain.

Among the rivers used for agriculture in the territory, Jabonmayo is one of the most important ones. Jabonmayo is tributary of the Urubamba-Vilcanota river and is used to irrigate Pampamarca district. This river is the main tributary to the Pampamarca lake and supplies water needs for agricultural activities in four villages (two villages in every district). The resource allocation for the area that belongs to the territory is governed by the Central Commission of Jabon Mayo, registered under the National Water Authority, and integrates four irrigation committees: Pamparqui, Pabellones, Jilayhua y Colliri[9].

Other important rivers in the territory used for irrigation are Chacamayo and Huatha, both tributaries of the Urubamba-Vilcanota river**.** Chacamayo starts from the regulated outlet of Pampamarca Lake and irrigates territories of four districts: Pampamarca, Mosoc Llacta, Acopia and Tinta. (The last one is not part of the territory of study.) The water resources from this river are allocated by two irrigation commissions, registered under the National Water Authority: Pampamarca - Tinta and Mosoc Llacta - Tactabamba.

The Huata River is tributary of the Pomacanchi lake, and is one of the most important water sources used for irrigation in Pomacanchi district villages[10]. This river irrigates areas under the Meriss Inka irrigation project whose intervention has focused one the provision and improvement of hydraulic infrastructure in four villages of Pomacanchi. The irrigation system includes gravity and sprinkler methods. Farmers using irrigation in these areas conform the irrigation commission of the same name (Meriss Inka – Manzanares Pomacanchi), registered under the water authority.

3.3 Economic activities

Due to its particular location (surrounded by lakes that temperate the ecosystem), the territory benefits from optimal climate conditions for agricultural development and livestock production. While agricultural activities were traditionally carried out to provide traditional crops for household self-consumption, the production of fodder crop aimed at supporting dairy farming activities has

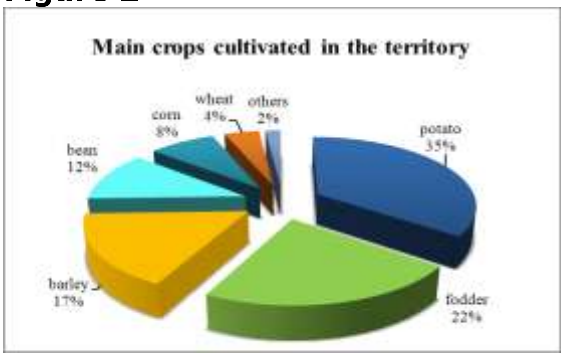
[9] Only Pamparqui and Pabellones belong to the area of study.

[10] The Manzanares-Pomacanchi irrigation system vinculates four villages of Pomacanchi district (Manzanares, Pomacanchi, Chosecani and Pomacanchi) and it manages water resources of Huata river and two streams: Hunura and Mayuñan.

gained more interest by farmers and is progressively substituting other traditional crops in the territory.

Regarding the agricultural productive structure, in Cuatro Lagunas small scale farmers use their production technology to produce mainly traditional crops (See figure 2). The traditional production is primarily aimed at household´s self-consumption and coexists, alongside, with fodder crop production aiming at cattle feeding and sustaining their dairy production for the market.

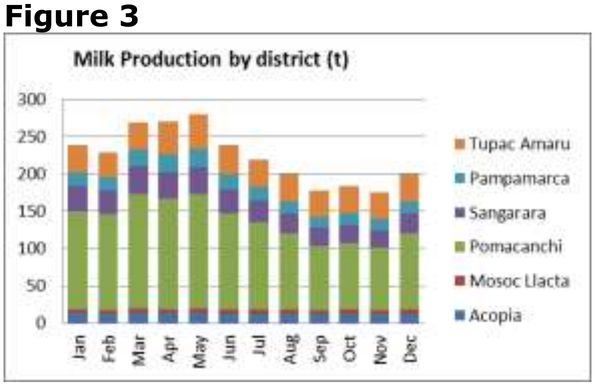
Figure 2



Source: DTR Survey

According to the Ministry of Agriculture of Peru, Pomacanchi, Pampamarca, Tupac Amaru and Sangarara are the most important dairy producer districts in the territory (See figure 3)

Figure 3



Source: Ministry of Agriculture

The fodder crop production in Cuatro Lagunas has been dynamically increasing in response to the dynamism of production and marketing opportunities for dairy farming. Dairy farming is a recently developed income generation strategy that was initially promoted by international cooperation agencies in the territory and is currently being supported by more local governmental initiatives (at the district level)[11]. The increase of farmers' switch from agriculture to dairy farming has been spread across the territory during recent years; however, this switch has also driven more demand for and increased stress on water resources. To meet the market's increasing demand for dairy products, farmers have converted more cropping land towards fodder crop production areas. This permanent-type crop production has led to increases in demand for irrigation water throughout the year, particularly in the dry seasons (from May to October).

During the dry season, the main water source available is surface water running over the territory. The water resource is conveyed across the existing irrigation infrastructure with a certain flow capacity; thus in the peak seasons it can result scarce and rival, being subject of contested situations between users and communities. The increasing demand for irrigated water has raised concerns about the water supply and its allocation across the territory. It has also raised concerns about conflicts surrounding communities' common water resources and the need for institutional support over the water resources allocation together with managerial and technical empowerment over the use and maintenance of the irrigation infrastructure.

[11] Local authorities are promoting the implementation and functioning of local milk processing plants in order to attend, with local resources, the demand for milk and dairy products by social programs in the territory.

4.- Irrigation Institutions in Cuatro Lagunas

Based upon the information available on irrigation in Cuatro Lagunas, this paper only focuses on the institutions governing water resources allocation in the territory. The first part of the analysis will focus on the legal and economic framework given by the National Water Authority. The second part will describe the communal framework governing water resources allocation by the customary laws. Finally a brief discussion about the coexistence of several institutional regimes in the territory governing water allocation will be presented.

4.1 The Peruvian State legal framework on water resources use

The national institution that governs water resource use in Peru is currently going through a process of reforms. The reforms started at the national level in 2009 when the institutions governing water resources have been restructured from the multi-sectorial and multi-governmental instances into one integrated authority for water resources management and a new basin -level framework.

The highest national level agency for the governance of the water resources in Peru is the National System for Water Resources Management (SNGRH)[12]. This institution involves authorities from every productive sector, regulators, operators and final users' representatives. The main purpose of the SNGRH is to integrate actions from multi-sectorial and multi- governmental levels towards a more participative planning and management of water resources at a basin level.

The National Water Authority (*Autoridad Nacional del Agua,* ANA), created in 2008, is the highest technical authority in the Peruvian National System for Water Resources Management. Among its main responsibilities, ANA establishes rules and regulations for the promotion of sustainable use of water resources. Furthermore, ANA is the authority responsible for defining the charges for water use and for wastewater discharges into natural water bodies. Within the Peruvian territory, the institutional structure of ANA has been decentralized

[12] The National System for Water Resources Management of Peru (Sistema Nacional para la Gestion de Recursos Hidricos, SNGRH) involves the following government bodies: The National Water Authority, The Ministry of Agriculture, Ministry of Housing, Construction and Sewerage, Ministry of Health, Ministry of Production and Ministry of Energy and Mining. Additional organizations involved include local and regional government, agrarian and non-agrarian water user associations, peasant and native communities and other hydraulic projects.

through two operative instances: the Administrative Water Authorities (AAA) and the Local Water Authorities (ALA)[13].

The Administrative Water Authority (*Autoridad Administrativa del Agua,* AAA) is responsible for the water management at the basin level. It is required to implement and execute the policy guidelines stated by the central Water Authority (ANA). There are 14 Administrative Water Authorities in the Peruvian territory, basically delimited according the Peruvian hydrography, on the basin level. (ANA 2009a).

The Local Water Authority (*Autoridad Local del Agua,* ALA) is the operative unit for the AAA at the lowest administrative instance for the National Water Authority. ALA boundaries correspond to what the Ministry of Agriculture has defined as non-divisible hydrographical units (ANA, 2009). Currently there are 70 ALAs in total in Peru. Among the main responsibilities of the ALAs is to grant water use permits according to the law of water resources as well as to approve the fees that will be charged for the use of water resources .

Administratively, most of the territory of Cuatro Lagunas belongs to the AAA Urubamba-Vilcanota and a small part of the territory belongs to the AAA Pampas Apurimac. Within the AAA Urubamba-Vilcanota, Cuatro Lagunas is under the jurisdiction of ALA Sicuani which has the bigger number of users and irrigated area in the AAA. (See table 6). The other part of Cuatro Lagunas, within AAA Pampas Apurimac comes under the jurisdiction of the ALA Alto Apurimac-Velille.

Table 6: Local Water Authorities within AAA Urubamba Vilcanota*

ALA	Number of users	Nº Chief collecting points	Total Area (Ha)	Irrigated Area (Ha)
Sicuani	22,015	100	11,277.39	10,183.88
Cusco	18,136	95	10,445.17	9,032.27
La Convencion	4,002	90	16,747.00	3,491.08
TOTAL	**44,153**	**285**	**38,469.56**	**22,707.23**

*Note: The irrigated area only accounts for the registered water user associations
Source: ANA (2010a)

It is important to mention that this new administrative division of the governance of Cuatro Lagunas between two ALAS and two AAAs means a change for

13 Besides these administrative decentralized organs, there is also the Council for Water Resources at the basin level, which involves participation of the civil society and policy makers for the planning, coordination and cooperation in the water resources use.

the operationalization of water rights acquisition in part of the territory, specifically for the villages in Pomacanchi and Tupac Amaru districts. Before the reform, the territory was completely within the jurisdiction of the Technical Authority of the Sicuani Irrigation District (ATDR Sicuani). The administrative process of implementation of this reform is still taking place[14].

4.1.1 The Water Resources Law

The Water Resources Law 29338 (Ley de Recursos Hidricos, LRH), was introduced in 2009 (its regulatory framework was introduced in 2010). This law regulates the use and management of the water resources and its "confined goods" in the Peruvian territory. It replaced the previous General Water Law (DL 17752) and its former regulations governing water use from 1969. According to the LRH, all Peruvian water resources constitute national heritage and are considered public goods. Thus, its use is regulated by the State and, conditioned to its availability; the use is permitted only when it does not cause detrimental effects on third parties.

For the Peruvian water law, the "user" is defined as any person or entity (including any institution) that holds official water rights such as authorizations, permits, licenses or any nominative title issued by ANA (ANA 2009b, 2010b). Water rights are issued individually and also collectively (by blocks) to any formal and registered association of users such as irrigation committees and irrigation commissions.

In addition, the law acknowledges three types of water resources use, which in order of priority are: primary use (used directly from primary source for direct human consumption and cultural or religious use. No water right is required and no fee), population use (after treatment, used to meet human basic needs, requiring both water rights and fees) and productive use (water used by any productive process, whether agricultural or industrial, again, requiring both water rights and fees). Among the productive uses, the agricultural use is one of the most important sectors requiring water for the productive process. (ANA 2009b, 2010b)

According to the water resources law, the local institutions acknowledged to govern irrigation water resources are: Board of users, Irrigation Commissions and Irrigation Committees. These institutions represent the final user, under the administrative authorities. Every committee is in charge of the water allo-

[14] Due to this process, there is still no updated information available about registered committees within the side of the territory that belongs to AAA Pampas Apurimac.

cation and the cleaning and maintenance activities for the hydraulic infrastructure. (ANA 2009b, 2010b)

User Committees Also known as irrigation committees, they are the first level institutions to grant water rights and distribute water for agricultural use in Peru. The committees are responsible for the operation and maintenance of the hydraulic infrastructure (*infrastructure operators*). Committees should promote active and permanent participation for the implementation, operation, cleaning and maintenance of hydraulic infrastructure. The committees represent their members within the irrigation commission and also support all its delegated activities. The members are any agricultural producer who share hydraulic infrastructure that: (a) is part of a sub sector within one irrigation commission, and (b) delivers or distributes water from a single water collecting point from surface -or groundwater source.

User Commissions They are also known as Irrigation commissions. They are higher level agencies and represent user committees at the Board of Users. Furthermore, user commissions support and coordinate the delegated activities for the committee members. The irrigation commission associates user committees associated under a common hydraulic infrastructure.

The Board of users is the highest level agency that represents water users for the agricultural sector under the water authority. It is constituted by irrigation commissions and irrigation committees (for those committees not associated within any irrigation commission) and is the main institution that sets the water remuneration for the use of water and the water fee for the use of hydraulic infrastructure. The board of users is in charge of the promotion and development of irrigation projects as well as technical assistance and extension services for its members.

4.1.2 Water rights granted by the State

The use of water for productive purposes is subject, according to the LRH (2009), to water rights acquisition granted by the ANA. The water rights are issued, modified, renewed or repealed by administrative resolutions from the ANA, according to the law. The water rights granted for agricultural use, specifically for irrigation, are: Licenses and permits. (ANA 2009b, 2010b)

The License is a water use right granted for the use of the resource under an infinite period of time depending on the duration of the activity for which it was granted. It is given only if there are available water resources. The License is non-transferable. It can be issued individually and by blocks (common water resource use). The licenses given by blocks are issued for any water user organization acknowledged by ANA that shares a common chief water allocation point. The agricultural agents eligible for licenses by block are the irrigation commissions and the irrigation committees.

<u>The permit</u> is an authorization for the use of surplus water. It means that the use of water is only authorized after all who are licensed to exercise their right to use water.

The Peruvian State acknowledges the right for the rural peasant and indigenous communities to use water resources that run over their territories as well as the basins from where they originate. However, these communities are also obliged to register officially and pay the water remuneration to the State, receiving the same treatment as any other user under the regulation of the ANA. This regulation is seen by communities as the privatization of the rights which does not agree with the payment to the State.

4.1.3 Composition of the water fees for agriculture

Water resources are considered Peruvian national heritage and property of the State. Thus, the use of this natural resource is subject to economic remuneration to the State which has compulsorily to be paid to the Peruvian State by every user (individual or institution) that holds the rights for it (license or permit) and is accessing the resource for any productive purpose.

The ANA is the authority responsible for the establishment of water fees (and the methods of estimation) to be charged for the use of water in the agricultural sector. Operationally, the ANA receives the technical proposal for water fees by the board of users. After approval, by ANA, the board of users is also in charge of charging it and taking control of it. It is important to mention that the technical proposal has to be set following the established method of estimation, considering the criteria of self-sustainability and affordability.

The water fees for irrigation have two main components, the economic remuneration and the tariff for the service of distribution. The former is paud to the Peruvian State and the latter is paid to the the infrastructure operators (water user associations) for the use of hydraulic infrastructure. According to the information provided by the Sicuani board of users, in 2011 the water fee in the territory was 12 Peruvian soles per hectare (US$ 4.36). The structure of the fee is composed as follows:

Table 7: Structure of water fee in the territory

Percentage	Description
10%	Remuneration to the State
1%	Remuneration for the National Board of users
23%	Administrative cost for the Sicuani Board of users
66%	Cleaning and maintenance costs by the committee/commission

4.2 The Customary law governing water resources allocation

As with most parts of the highlands, the presence of indigenous communities is still highly representative in the productive structure along the territory. According to the Cusco regional government, the communal land tenure represents 83.80% of the total territorial land of the Acomayo province and 56.34% of the land in the Canas province (Gobierno Regional Cusco, 2010).

The social organization of Cuatro Lagunas is based on rural communities, supported by customary law (Rural Communities Act, Communal Assembly agreements). Every community is formally represented by the highest authority of the Community Assembly, the communal president, with a directive board elected every two years by a general assembly election (Escobal and Ponce 2010)

Regarding the governance of water allocation in the territory, the customary system grants water rights to farmers who are active members of the community and have access to any irrigation infrastructure system. The water rights acquisition is granted by the communal authority on the basis of socio-territorial mechanisms. The community considers every water source that runs within the communal territory to be communal property. Thus, under the customary laws, community members have right to access natural resources, on equality of opportunities and with no need to pay economic remuneration to the communal authority. In the case of irrigation, the access is tied to the existence of irrigation infrastructure, and this feature makes a difference on the equality of opportunities to access. In some communities, it is still possible to find irrigated land evenly distributed among community members, especially in communities where it has been allocated on the basis of the equal share of land for every member. However, in most cases the irrigation only benefits farmers whose land is endowed with functioning irrigation infrastructure and water resources running over it.

Within the communal organization there are specialized committees that govern irrigation and coexist with registered irrigation institutions governed by the State. These specialized committees govern irrigation either under the communal authority governance or under a more independent regime. The difference among these two regimes is the scope for intervention and support by the central communal authorities. In the independent regime the managerial decisions and the sustainability of the institution is less dependent or independent from the central communal authority. According to Escobal and Ponce (2010), the current productive structure in Cuatro Lagunas is giving more autonomy to these committees, which are becoming more independent from the central communal authority.

Finally, the irrigation regimes under the customary law do not charge any monetary remuneration for the use of water (as opposed to the economic remuneration to the state that is charged by State), but in some cases, especially for the independent regimes, there is a monetary fee charged by committee directives in order to support cleaning and maintenance activities of irrigation infrastructure. The value of this fee is determined by the committee's general assembly of users, on the basis of one user one vote. In both cases (centralized and independent regimes), the provision of labor force during cleaning and maintenance activities is compulsory in order to be eligible for water rights and constitutes the main non-monetary contribution to the system.

4.3 A dual framework on water resources allocation

From the previous subsections we can see that irrigation for agriculture is allocated under the governance of two legal systems: the customary law, acknowledged by local institutions, and the Peruvian State. Despite the fact that registration under the national water authority is compulsory in order to acquire status of legal entity, in some parts of Cuatro Lagunas (as in most parts of the rural highlands) irrigation water is being allocated by customary laws and communal rules of governance.

The most important irrigation institution allocating water in Cuatro Lagunas is the irrigation committee. It is the lowest level agency that represents irrigation users under both legal systems: the registered and unregistered. In both cases, the governance of this institution is defined by internal statutes that establish the bundle of rights and obligations for members.

Due to the fact that not all irrigation committees are registered, it is difficult to know the real number or irrigation committees allocating water in the territory. According to Escobal and Ponce (2010) in the year 2009 there were approximately fifty irrigation committees in the territory. In 2012 the National Water Authority reported from its administrative records of water rights (RADA), 24 registered irrigation committees, 14 of them represented by eight registered irrigation commissions. The registration started at 2009 and most of the committees registered in 2010 (See map on Appendix). One of the first water user associations registered is the Manzanares-Pomacanhi commission that governs water resources in four villages of Pomacanchi district.

There is no official data regarding total irrigated land in the area neither on how much land is irrigated with gravity or sprinkler systems. The data from the National Water Authority in 2010 (See table 8) gives us an estimation of the total irrigated land held by every registered committee and commission that holds water rights; however, these figures are underestimated as they do not take into account the irrigated land managed by famers who are grouped in unregistered committees.

Despite the limited information about the real figure of total irrigated land in the territory, it is possible to have an estimated number of how atomized the irrigated land managed by every farmer is. From the data reported by ANA (2010a), we can see that a single farmer, from a registered committee in the Vilcanota basin, manages on average 0.33 irrigated hectares. (See Table 8). Approximately the same figure was obtained from the semi-structured interviews to 33 committee representatives in this basin[15]. In this case, it was possible to estimate a difference between registered and unregistered committees. A farmer from a registered irrigation system seems to manage a slightly bigger piece of land (0.41 irrigated ha), on average, compared to the average managed by a farmer from a non-registered committee (0.28 irrigated ha).

[15] It is important to mention the differences in the type of data reported. In the first case, the reports by ANA are records verified by the authority. In the case of the interviews, this data is estimated and reported by the president of the irrigation committee at the time of the interview.

Table 8: Irrigation commissions registered in Sicuani ALA – Vilcanota Basin

Irrigation commission	Villages	District	Nº of users	Rivers/ springs	Irrigated Area (Ha)	Average Area/ user (Ha)	Flow (l/s)
Pampamarca Tinta	Pampamarca Pamparqui Tinta	Pampamarca Tinta	725	Chacamayo	500	0.69	500
Mosocllacta Tactabamba	Mosoc Llacta Tactabamba	Mosoc Llacta Tacta Bamba	301	Chacamayo	190	0.63	123.75
Jabon Mayo	Pabellones, Pampamarca Jilayhua, Colliri	Pampamarca Yanaoca	650	Jabón Mayo	379	0.58	380
Manzanares Pomacanchi	Manzanares Chosecani Santa Rosa de Mancura Pomacanchi	Pomacanchi	2,647	Huata Toccora y Hunuras Huayconñan Mayuñan Huata	364	0.14	100
Marcaconga	Marcaconga	Sangarara	30	Ccasaspata	--	--	13
Thume	Thume	Mosoc Llacta	42	Puquiosimi	10	0.24	2
Hurasayco Mosocllacta	Mosoc Llacta	Mosoc Llacta	130	Pitupuquio	22	0.17	11
Riego por Aspersión Koscca-Mosoc llacta	Mosoc Llacta	Mosoc Llacta	87	Chacamayo	25	0.29	25
TOTAL			4,842		1,580	0.33	

Source: National Water Authority (2010)

From the information gathered in the semi-structured interviews, we can identify three types of institutional regimes on which irrigation committees allocate water resources to farmers. Two of them govern allocation under customary laws and the third one governs under the national legal scheme. Among the ones that are governed by customary laws, there are centralized committees, which are still financially and administratively dependent from the communal authorities, coexisting with a more independent regime, the committees constituted and managed by irrigation users. There is an important difference between these two regimes, it has to do with the degree of communal authority's involvement on managerial decisions and economic support.

The fact that the independent regime governs water allocation more autonomously makes a significant difference regarding aspects such as governance and sustainability of the irrigation system. In this vein, we can see that centralized regimes are subject to certain managerial decisions by communal authorities (who represent not only users but all the community members) which could impose extra coordination costs. This is especially the case when decisions regarding irrigation are not priority of all community members since not every member has access to irrigation.

In addition, the independence of irrigation committees in terms of managerial and financial decisions from the communal authority imposes the incentive for being self-sustainable on its managerial decisions. From the interviews to irrigation committees, most independent irrigation committees establish a water fee to cover monetary costs for cleaning and maintenance of canals. In contrast, the water users associations that are still centralized by the communal authority are mostly supported by the communal budget for the cleaning and maintenance activities. The water fee charged is the indication that the of irrigation system is generating its own resources, mainly devoted to cover infrastructure maintenance, in order to provide better irrigation services for its members. It could impact positively on the productive levels by farmers if proper infrastructure and better irrigation services are provided by more independent regimes.

Regarding the differences on the two legal systems, the most notable difference among the customary law and the State law comes from the definition of the water resources property, either considered property of the Peruvian State or property of the community. From the State law, water resources are property of the Peruvian State and, from this point of view, the water right is granted only to the services provided by the resource. Thus, the law establishes that every user of these services should pay the economic remuneration to the State. In the second case, water is viewed by communities as common pool resources, and the water right grants full property over the resource, claimed under historical and socio-territorial principles. For communal users, any payment of economic remuneration for the services provided by the resource to the State is viewed as the privatization of the resource.

There are differences regarding the bundle of rights acknowledged by the two legal systems. The State acknowledges the right to access and withdraw, individually or through registered committees, and the right to take part in managerial decisions on the operability of the system, trough the General Assembly of users. One of the managerial decisions in which the user take part is for example the establishment of the water fee, which is decided by vote of all members of the General Assembly of users, on the basis of one user -one vote[16]. However, the rights of alienation and exclusion remain in the side of the State. It means the law does not provide managerial rights that allow users to trade the license or to exclude other users from using it. (See table 9). For the committees governed under customary law, the full bundle of rights is acknowledged to members: The right to access, to withdraw and to take part in all managerial decisions.

Table 9: Bundle of water rights acknowledged to water users

		Governed by Customary Law	
	Governed by the State Law	Independent committee	Committee centralized by the Community
Access	*Y*	*Y*	*Y*
Withdrawal	*Y*	*Y*	*Y*
Management	*Y*	*Y*	*Y*
Exclusion	*N*	*Y*	*Y*
Alienation	*N*	*Y*	*Y*

Note: Y=Yes, N=No

Furthermore, there is a difference regarding the type of right acquisition. In the case of registered committees, the members are granted *official* water rights, named permits or licenses, individually or "by blocks", for which farmers have to be officially registered under the irrigation institution as legally constituted. These water rights are acknowledged as official legal title by the Peruvian State. On the other hand the regimes governing allocation under customary laws grant water rights claimed under historical and socio-territorial principles which provide *de facto* water rights to community members. These water rights are not registered as official legal titles and could be unacknowledged by users from other communities.

16 The water fee decided under this scheme is presented as technical proposal for approval to the ANA.

According to the distribution and concentration of the official water user institutions in the territory (see map in Appendix), it seems that the formality of this type of acquisition provides more secure rights, especially in the context of common water resources shared by several communities and the prevalence of contested situations for the allocation of the resource.

Regarding the bundle of obligations of these institutional regimes, the most common important characteristic among all of them is the contribution of labor force for cleaning and maintenance activities as compulsory (non-monetary) contribution in order to be eligible for water rights and water turns. Furthermore, there are obligations regarding the attendance of activities and assemblies organized by committee directives. In most cases, for all regimes, the non-assistance to these activities is charged with a fine.

On the other hand, the most important difference among the three institutional regimes is the payment of the water fee (monetary contribution). The officially registered regime imposes the payment of water fees to cover a more complex set of items (remuneration to the state, remuneration to the national board of users, administrative payment to the Sicuani board of users and cleaning and maintenance of infrastructure). In contrast, the regimes under customary law establish a simpler structure of water fees, aimed to cover only cleaning and maintenance activities of the irrigation infrastructure. Furthermore, in most cases the centralized irrigation regime does not charge any water fee, and is mostly supporting any monetary costs on the side of the communal management.

5.- Econometric estimation and data specification

This section presents the empirical analysis implemented to assess the relationship between irrigation institutions and technical efficiency by small scale farmers. The analysis in this section is divided in three subsections. The first part presents the econometric model implemented to estimate technical efficiency levels for every farmer, the second part presents a characterization of the households in the sample and finally the last subsection presents the estimation results.

5.1 Econometric model

The parametric stochastic frontier (PSF) model presented in this section is aimed at measuring the ability by farmers to generate outcome at the production possibility frontier. This means, the ability to generate the maximum possible output given a set of inputs and a certain level of technology. Thus, technical efficiency is associated with the way a producer uses his best possible practices in order to get the maximum attainable level of production.

The stochastic production frontier models allows the possibility to account for the possible deviations by farmers from its optimal production frontier coming from inefficiencies on the side of the producers, and also inefficiencies from other external factors, i.e. uncontrollable by farmers (the environment, the topography, the climate, or events of luck). Thus the stochastic frontier model is incorporating a compound random element in the production function to take into account these two disturbances (See equation 2).

The stochastic frontier production function for every farmer will be defined as:

$$Y_i{*} = f(X_i;\beta) + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$\varepsilon_i = \exp(U_i - V_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where Y_i * represents the production possibility frontier for farmer "i" or the maximum amount of product that could be obtained by farmer "i" given a set of inputs X used by each individual "i". β is the unknown parameter that represents the contribution by each input on production.

The equation (2) defines the random disturbance component in the production function. Each element of this component is assumed to be independently distributed and independent from each variable in the model. V_i is independently and identically distributed with a normal distribution $N(0, \sigma_v^2)$, and is associated with random factors that are out of control by the farmer. Finally, the term U_i is the random error, assumed to be non negative[17] with a half normal (non-negative truncations of the $N(0, \sigma_v^2)$) or exponential distribution and is associated with the technical inefficiency by farmer. this non-negative disturbance factor includes the effects controlled by the producer and crop management, the effort of employees or the appropriate use of pesticides, which are directly associated with the named technical inefficiency.

The estimation of technical efficiency will be implemented by using a Cobb-Douglas production function in the equation (1). The inference about the parameters will be obtained by using maximum likelihood estimators, under the assumptions given about the distribution of the random component in the equation (2). After estimating the parameters, the technical efficiency level for each farmer will be computed as the expected value of the inefficiency term conditioned on the disturbance composite term (ε_i) Defined by the following ratio:

$$TE_i = \left[\exp\left(-V_i\right)/\,\varepsilon_i\right]..................(3)$$

The estimation of the Cobb Douglas production function here will allow different levels of productivity associated with different proportions of use of inputs, such as labor, seeds, fertilizer, labor, capital and pesticides. A more flexible functional form (translog), has been explored but the number of parameters involved is considerably greater. The Production function will be defined by the following variables:

$$\begin{aligned} LnY_i = \; & \beta_0 + \beta_1 Ln(Land_i) + \beta_2 Ln(Seed_i) + \beta_3 Ln(Fert_i) + \beta_4 Ln(K_i) \\ & + \beta_5 Ln(Labor_i) + \beta_6 Ln(Pest) + \beta_7 D_{i,K} + \beta_8 D_{i,Pest} \\ & + \beta_9 Fodder + \beta_{10} Irrig_i + \beta_{11} Watershed_i + V_i + U_i ....(4) \end{aligned}$$

Where:

- The subscripts i refer to the i-th farmer in the sample. Ln denotes logarithms to base e;
- Y: Denotes de value of total agricultural production harvested in the season

17 The non -negative restriction on the term U, implies that exp(-U) has values between zero and one.

- Land: Is defined as the total amount of cropping land in the season, measured in hectares.
- Seed: It represents the total quantity of seeds used during the season. It includes self-provisioned and bought seeds[18].
- Fertilizer: is the total amount of fertilizer. It includes manure and other fertilizers used.
- Pesticide: Represents the total amount of pesticides used. It is reported as the total expenditure in pesticides. In this case the survey does not provide information on quantities used.
- Capital: It represents the capital and equipment used for ploughing.
- Labor: Is the total amount of labor defined as days of work by an adult male equivalent. It includes family labor, communal labor "ayni" and hired labor.
- D_k: Is a dummy variable equal to one if the farmer does not use capital or equipment for ploughing, zero otherwise.
- D_{pest}: Is a dummy variable equal to one if the farmer does not use pesticide, zero otherwise[19].
- Fodder: Is a dummy variable incorporated in the model to control for the differences in the agronomic management of fodder crops in comparison to the rest of crops (transitory).
- Irrig: Is a dummy variable equal to one if the farmer reported access to irrigation for at least one of his land plot. Zero otherwise.
- Watershed: Is a dummy variable that incorporates the information regarding geographical and hydrological context for the farmer. It takes the value of one if the farmer is located within the Vilcanota basin. It takes the value of zero for Apurimac watershed.

Based upon the information contained in the survey it was not possible to incorporate water quantities used in agricultural production. In this particular case, the information from the survey about the value of expenditure in irrigation water is not a good proxy for the quantities used because water is also used by farmers without any monetary payment. As we have seen in the previous section, farmers pay for irrigation or not depending on the institutional regime that governs their irrigation system. Thus, expenditure on water does not provide correct information on quantities of water used; however, it provides information about the allocation regime in which the farmer is inserted.

[18] It is aggregated for every seed of the production portfolio by farmers by using a quantity index to assure comparability. The same procedure was followed for the aggregation of fertilizers and capital

[19] Following Batesse (1997), these dummies Dpest and Dk for the input variables with zero value, will allow to estimate unbiased parameters for the Cobb – Douglas production function in (4).

This effect of the institutional regimes governing water allocation will be analyzed in the last part of this section.

5.2. The sample

The data used in this section is based on the DTR Survey data collected by GRADE from small holder farmers located in Cuatro Lagunas, Cusco, in 2009. The sample was drawn from four out of the six the districts in the territory: Pomacanchi, Sangarara, Pampamarca and Tupac Amaru; and two provinces: Acomayo and Canas, in Cusco region. The survey used in this study provides detailed information of agricultural production and costs. Furthermore the survey contains data about other income generation activities as well as socioeconomic characteristics and assets at the household level.

We can see that, within the area of study, most farmers have access to irrigation for at least one of their plots (80%). Furthermore, irrigation is used at the beginning of the sowing season due to absence or delay of rains but is mostly used (60% of farmers who access to irrigation) throughout the year specially to irrigate fodder crops. There are significant differences regarding the proportion of the sample with access to irrigation among the two basins in the territory. A significant higher proportion of irrigation is concentrated in the Vilcanota basin (85%) and 15% of the farmers who use irrigation in the sample are located in the Apurimac basin. Within the Vilcanota basin the farmers who use irrigation permanently during the year represent 44% of the subsample, where the fodder production is significantly higher as well (77%). For these farmers, the share of irrigated over total land is 51% on average.

Table 10 summarizes the average characteristics of farmers and relevant information on agricultural assets and agricultural production. The table is aimed at comparing differences among farmers with and without irrigation. The definition of access in this case involves access at least for one plot and at least once in the year. The third column presents information for the overall sample. Among the most important characteristics we can see that the majority of heads of households over the sample have only primary school -or less – as their maximum educational level attained (56%). This number is significantly higher rate for farmers without access to irrigation (69%) compared to farmers with irrigation. There are other significant differences regarding household's characteristics. We can see significant differences on membership to productive and social organizations. Farmers with access to irrigation have in average more number of organizations in which takes part as a member. Besides, the value of household assets is on average higher for farmers with access to irrigation.

Regarding the productive assets, we can see that this sample mimics the plot size profile of the highlands, where small plots holding is the norm. The plot size in average is 0.11 ha but every farmer has on average 0.32 ha. There are no significant differences on the size of plots or total land hold by farmers with and without access to irrigation. A fragmentation land index was calculated[20] to explore differences in this productive asset by farmers, especially considering that farmers have in general several but atomized plots. This number gave a slightly higher value for the farmers that use irrigation. It means that probably they manage more plots in different areas, one of them with irrigation. After all, the differences in this index are not significant.

20 The Land fragmentation index has been calculated for every farmer as $IF_i = 1 - \left(\frac{\sum (a^2)}{(\sum a)^2} \right)$, where: a=size of every plot and *i*=farmer

Table 10. Characteristics of farmers in the sample

	Without irrigation	With Irrigation		Over all
Household characteristics				
Gender of household´s head (1=male)	0.9455	0.9605		0.96
Age of household´s head	41.53	42.75		42.51
Maximum edu. level reached by household head=primary education	69%	53%	**	56%
Maximum edu. level reached by household head=superior education	2%	8%		7%
Average household´size	5.073	4.735		4.80
Mother tongue is quechua	96%	96%		96%
Risk aversion (from 1 to 5, the higher value, the less risk averse)	4.041	3.778		3.83
Altitude of dwelling (m.a.s.l)	3,788	3,749	**	3,757
Located in Vilcanota Watershed	64%	85%		49%
Assets				
Average size of cultivated plots (in hectares)	0.11	0.10		0.10
Total cultivated land (in hectares)	0.2519	0.3317		0.32
Land fragmentation index	0.63	0.67		0.67
Productive assets (valued at median prices) (US dollars)	389.8	238		267.3
Household assets (valued at median prices) (US$)	60.42	135.6	*	121.1
Number organizations that the farmer belongs to (social capital)	2.091	2.5	***	2.42
% with access to credit during the last year	5%	11%		10%
value of livestock at median prices (US$)	1376	1574		1,536
value of cattle stock at median prices (US$)	698.5	846		818
value of dairy cows stock at median prices (US$)	232.1	295		283
Production				
% of farmers that received technical assistance in agriculture	29%	49%	**	45%
% of farmers that received technical assistance in dairy farming/livestock keeping	36%	50%	*	48%
% of farmers producing dairy products	47%	60%	*	58%
Average number of dairy cows per farmer	0.78	0.96		0.92
% of farmers with improved cattle breed	11%	14%		14%
% of farmers who produce fodder crops	24%	73%	***	64%
% of hired labor	4%	6%		5%
Value of agricultural production per hectare (US$)	5,946	4,368		4,672

Value of fodder crop production per hectare (US$)	79	481	**	403.10
Value of milk production per cow (US$)	183	310	*	287.60
Sample size	55	230		285

Note: Exchange rate used: 1 dollar = 2.91 soles
*** p<0.01, ** p<0.05, * p<0.1
Source: DTR Survey – GRADE

From table 10, we can also see that dairy farming and fodder crop production are the activities that are specially demanding irrigation in the territory. More farmers accessing to irrigation are devoted to dairy farming (60%) and there are more farmers producing fodder crops (73%) compared to farmers without access to irrigation. Finally the values fodder crop and milk per cow production are significantly higher for farmers with access to irrigation.

5.3 Empirical results

This section is divided in two parts. The first part will present the stochastic parameters of the technical efficiency model and the second part will present results on the analysis of the institutional effects from irrigation in Cuatro Lagunas on technical efficiency by farmers.

Regarding the stochastic parameters of the technical efficiency model, in the table 11 we can see parameters for the ordinary least squares and maximum likelihood estimates. In both cases, they correspond to the Cobb Douglas production function depicted in (4). The first column shows results from the Ordinary Least Square parameters which provide the average production frontier and are closely similar to the parameters obtained by maximum likelihood model, except for the constant term which is biased and is more accurately measured by the maximum likelihood method. (ML, column 2 in table 11)

Table 11: Stochastic Frontier Parameters

VARIABLES	(1) OLS	(2) ML
Land	0.270***	0.261***
	(0.043)	(0.042)
Seed	0.298***	0.280***
	(0.053)	(0.052)
Fert	0.228***	0.232***
	(0.050)	(0.048)
Labor	0.025	0.026
	(0.067)	(0.065)
Pest	0.037	0.034
	(0.073)	(0.068)
$D_{i,P}$	0.092	0.084
	(0.175)	(0.164)
K	0.119**	0.126**
	(0.060)	(0.058)
$D_{i,K}$	-0.149*	-0.180**
	(0.086)	(0.085)
Vilcanota Watershed	-0.414***	-0.413***
	(0.113)	(0.109)
fodder crop producer	-0.102	-0.103
	(0.100)	(0.092)
irigation	0.222**	0.234***
	(0.091)	(0.089)
Constant	4.569***	5.199***
	(0.493)	(0.496)
lnsig2v		-1.248***
		(0.234)
lnsig2u		-0.678*
		(0.386)
sigma2		0.795
		(0.145)
lambda		1.329
		(0.192)
Likelihood-ratio test of sigma_u=0 (chibar2(01))		3.640
Prob>=chibar2		0.028
Observations	285	285

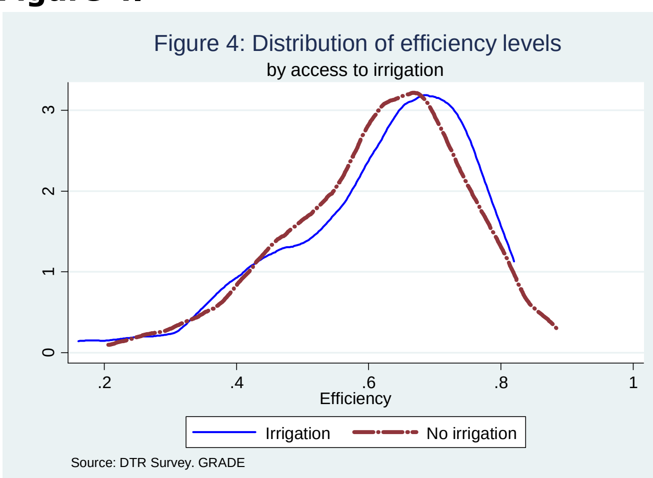
Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The value of Lambda provides the ratio among the standard error of the exogenous disturbance (V) and the standard error of the technical inefficiency by farmers (U). Based on that, it is possible to estimate the variance ratio of production that is explained by the technical inefficiency. For the preferred model (ML2) it is possible to calculate the share of the variance due to the inefficiency by farmers. Thus, it was possible to estimate that 64% of the total variance is explained by the inefficiencies of farmers. This result means that still 36% of the variation in production is explained by external environment factors which also constrain the technical efficiency by farmers in this territory.

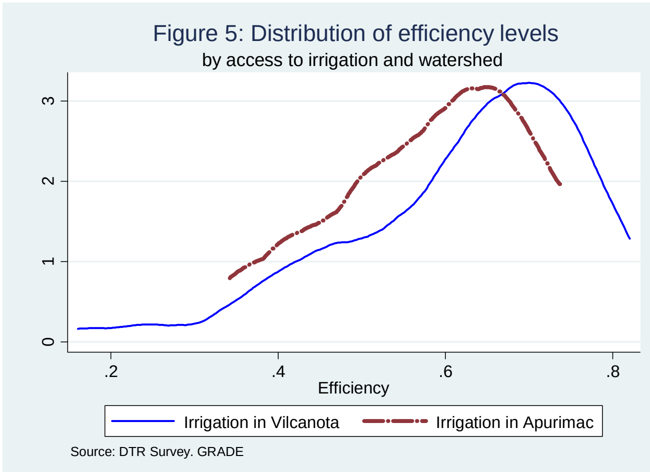
After the estimation of the parameters, it is possible to estimate the efficiency score for every farmer. The distribution of the technical efficiency scores are depicted in Figures 4, 5 and 6. We can see that the efficiency levels by farmers with access to irrigation are almost similarly distributed compared to the efficiency levels by farmers without access to irrigation. On average, farmers using irrigation have almost the same level of efficiency (61.6%) than farmers without irrigation (61.4), with no significant differences among them.

Figure 4.



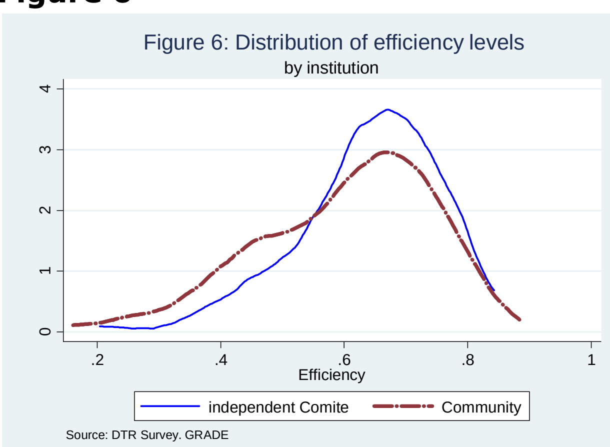
On the other hand, it was possible to explore differences among the two watersheds in the territory (See figure 5). The efficiency levels are, on average, closely similar for the two basins. However, exploring more in detail among farmers using irrigation during most part of the year for every watershed, it was possible to see that in The Vilcanota watershed farmers are on average slightly more efficient (62%) than in Apurimac (59%), with no significant differences. Looking at the distribution, we can see that Vilcanota has the most efficient farmers from the sample but also the less efficient ones. The distribution of the efficiency levels in Apurimac basin is more concentrated.

Figure 5



Looking into the institutional regimes allocating water to farmers with access to irrigation, we can see small differences on the efficiency levels. It seems that there is higher concentration of farmers who manage independent irrigation systems over higher efficiency levels compared to the case where farmers manage communal regimes for water allocation.

Figure 6



5.4. Irrigation institutions and technical efficiency

From the previous chapter it was possible to see that water resources allocation in Cuatro Lagunas is governed by several institutional regimes. Nonetheless, the data available and the time of the reform on water resources management by the State constraints the empirical assessment of the relationship between all the existing institutional regimes and technical efficiency by farmers. The survey data does not contain enough observations of registered water user associations, since most of them started registration in year 2010. Thus, the analysis will only focus on the two regimes governing water allocation under the customary law, one is governed by the independent regime (42% of household survey) and the other one is still centralized by the communal authority (58% of household survey).

To assess the relationship of these institutions allocating water in the territory, a truncated regression of technical efficiency determinants will be estimated. Additionally the dataset will be reduced to the subsample of farmers who reported use of irrigation (for at least one plot and at least some months during the season). In this vein, two institutional variables will be incorporated in order to capture the relationship between the institutional regime governing irrigation and its effects over the efficiency levels by farmers. The estimation results of this part of the analysis are presented in table 12. These results are presented over two subgroups of farmers. The first subgroup contains the full subsample of farmers who use irrigation and the second subgroup contains a smaller subset, the farmers who continuously use irrigation throughout the year.

From the estimation results over the first subsample, we can see that experience by head of household (measured as the age of head of household), is positively correlated with higher levels of efficiency. Furthermore, access to credit is also significantly contributing to higher levels of technical efficiency. Regarding the institutional regime governing water, the membership to the independent irrigation committee is positively significant on higher efficiency levels, compared to the centralized communal regime. This result provides evidence on the importance of more independent regimes allocating irrigation water on technical efficiency. There was no enough statistical evidence about the effects from the participation ratio (number of general meetings attended/number of general meetings programed) on technical efficiency, however.

Another interesting result was the significant relationship between the spatial diversification of plots and technical efficiency levels. It seems that agricultural activity in this territory leads to more efficient results when farmers diversify the productive units (plots) in terms of their altitude (low, medium and high). The variable that provides information on this relationship is the standardized index of spatial diversification (Herfindahl)[21]. It goes from 0 to 1, with 0 having the land spatially concentrated in one zone and 1 for the land completely diversified in the three zones. The sign and significance of this index tells us that spatial diversification of production contributes to higher efficiency levels. It seems that risk diversification would have positive impacts on efficiency by farmers.

From the geographical division of the territory, it is possible to see some differences on efficiency levels between particular areas. Compared to the base case in the estimation (the area of Tupac Amaru district that belongs to the Apurimac basin), the territory over the Pampamarca lake (surrounding Pampamarca lake' area and allocating resources from Jabon mayo and Chacamayo rivers) is significantly more efficient. This area involves sampled households from the villages of Pampamarca, Pamparqui and Pabellones and is the area that has more presence of independent irrigation committees in the survey.

On the other hand, looking at the role of institutions and technical efficiency within the subset of farmers who use water resources continuously throughout the year provided an interesting result (See Table 12). The dummy variable of payment of water fees (1=yes), introduced to account for differences in the institutional regime: independent vs. centralized, is positively and significantly affecting higher technical efficiency levels.

This would give evidence that more independent irrigation institutions governing allocation of resources provide better delivery service (trough better infrastructure cleaning and maintenance management) of irrigation and consequently have positive impacts on farmers' productivity.

The irrigation committee that is more independent is associated with requirements of water fees for members to support self-sustainability of the system whereas the communal regime system is still supported by the communal authority and consequently does not establish a water fee. From the previous chapter, the payment of a water fee is associated with more independence by the irrigation institution, and it means that the sustainability of the institution is based on the contribution and decisions by its members.

Furthermore, it seems that when the allocation and distribution is managed more independently, i.e. by the agents who are directly involved in the use of water, it may require less coordination efforts. This can reflect better services

21 The Herfindahl concentration index is defined as $H_i = \frac{1-\sum_{z=1} {a_z}^2}{1-1/3}$ Where *a* is the area of every plot, z is the location of the plot. There are three zones of location for z: low, medium and high *(pampa, intermedia and puna)*. i represents a farmer.

for irrigation. For example for infrastructure maintenance and cleaning activities, which are crucial for the system to work, it will be better organized in terms of frequency and coordination efforts by the group of farmers involved (compared to communal regime system where coordination costs might be higher involving communal authorities (and probably not only members of the irrigation system). In this sense, the significant result obtained for the variable of water fee means that decentralization and autonomy from the communal central authority is positively affecting the productive outcome by farmers who use irrigation. It is important to mention that the variable of committee is not significant anymore due to the loss of variability (most of them belong to an irrigation committee).

Finally, in this subset of farmers there are positive and significant effects by human capital, financial capital and social capital over the efficiency levels of farmers. Additionally the index of land plot diversification resulted significant for this subsample of farmers. For the human capital, the level of education and years of experience are also relevant. The result shows that having only elementary education or less is a critical characteristic that is negatively affecting the efficiency levels. In addition, more farmers' expertise is also explaining higher levels of efficiency. Regarding social capital, the dummy variable "Ayni" or communal work incorporated to control for the importance of social capital is significant and positively affecting the efficiency levels. It represents the importance of social capital and communal links for the productive efficiency by farmers. The importance of this variable is the fact that it incorporates information of the use of communal work for agriculture.

Table 12: Truncated regression of technical efficiency determinants

VARIABLES	(1) TOBIT	(2) TOBIT
Head of household has primary education only	-0.02	-0.04*
	(0.019)	(0.023)
Head of household has reached superior level	0.01	-0.06
	(0.036)	(0.051)
Age of head of household	0.01**	0.01**
	(0.001)	(0.001)
Number of Household members	0.00	0.01
	(0.005)	(0.006)
Altitude of dwelling	-0.02	0.04
	(0.100)	(0.145)
Access to credit	0.06**	0.08**
	(0.028)	(0.038)
Technical Assistance provided in Agriculture	-0.01	-0.02
	(0.018)	(0.023)
Herfindahl index (location of plots)	0.07***	0.09**
	(0.027)	(0.035)
Irrigation Committee (1=Yes)	0.06*	0.05
	(0.034)	(0.038)
Ratio of participation in committee activities	-0.05	-0.04
	(0.039)	(0.044)
Water fee (1=yes)	-0.01	0.05*
	(0.021)	(0.031)
Ayni – Communal work (1=yes)	0.04	0.10*
	(0.031)	(0.055)
Area – Pampamarca lake	0.08*	0.08
	(0.046)	(0.055)
Area-Pomacanchi, Apurimac basin	0.11*	0.07
	(0.061)	(0.083)
Area- Pomacanchi village, Vilcanota basin	0.04	0.07
	(0.050)	(0.059)
Area-Other villages, Vilcanota basin	0.05	0.01
	(0.045)	(0.058)
Area-Sangarara	0.03	0.04
	(0.046)	(0.054)
Constant	0.49	0.13
	(0.407)	(0.595)
Sigma	0.13***	0.12***
	(0.006)	(0.007)
Observations	228	138
Pseudo R-cuadrado	-0.132	-0.249

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

6.- Conclusions

The presence of irrigation institutions on water resources allocation is relevant to govern the access to irrigation and affects agricultural productivity by small scale farmers.

The case study of water institutions and technical efficiency in Cuatro Lagunas is noteworthy. This territory located in the Peruvian highlands, has shown an increasing dynamism of agricultural production that is driving more demand for water resources. This study presents evidence that Cuatro lagunas, being a territory documented by the literature as traditionally governed by centralized communal institutions, is now changing its institutional framework giving room to more autonomous institutions and more presence of the State law.

This study finds that in Cuatro Lagunas coexists the national legal framework with the customary law. The main differences between these two frameworks are (1) the different scope of the bundles of rights confined to each type of water right. The customary law provides a wider scope on managerial rights including rights to take part on alienation and exclusion decisions. (2) The different type of rights: i) property of the services provided by the resource and ii) property of the resource. The legal system provides rights on the services provided by the resource, in this case the ownership remains in the side of the State. In contrast, the customary law provides water acquisition implying the ownership of the resource by community members claimed under historical and socio-territorial principles. (3) The different type of water acquisition. In the case of rights granted by the State, the rights are acknowledged as official legal titles. Official registration and legally constitution is needed in order to acquire rights. On the other hand, customary law rights are not acknowledged as official institutions by the State.

Furthermore, this study presents evidence about different regimes governing water allocation within the customary framework: the independent and the centralized regimes. The main difference between these two regimes is the degree of dependence from the communal governance and consequently the difference in the management and provision of irrigation services.

Being an officially registered institution or not is not legally constraining the operability of the institutions allocating water in the territory. There are several non- registered irrigation committees coexisting with registered institutions. However in the areas with more presence of potential contested situations over the water resources, especially where common resources are shared by several communities and villages, there is more presence of officially registered committees. It seems that a water right by the State is considered a secure right that assures mutual acknowledgement between communities sharing water resources. In this vein, the area of the Pampamarca lake is noteworthy. This area has faced contested situations in previous years for the use of the resource (Alegria and Estrada 2010). Now in this area there are three registered irrigation commissions allocating irrigation water for the communities of Pampamarca, Pamparqui, Pabellones, MosocLlacta and Tactabamba. These communities share common water resources from the Jabon mayo and Chacamayo rivers, the former is affluent of the Pampamarca lake and the latter is effluent of this lake.

It seems that the dynamism of agricultural activities are driving higher demand for irrigation water and in turn driving the need for more independent institutions to govern allocation with less dependence on the communal regime and with more autonomy. Furthermore, in some areas, the increase in demand is driving the need for a broader level institutional regime to ensure mutual acknowledgement of water rights. This is specially the case for water resources shared between communities.

The empirical analysis of this study shows that there is a significant association between higher levels of technical efficiency and the participation in more independent institutional regimes allocating natural resources. Furthermore there is evidence on the positive relationship of higher levels of technical efficiency with higher levels of human capital (education and farmer expertise) and access to financial capital by farmers.

In Cuatro Lagunas, allocating water under more independent committees is correlated to higher levels of efficiency, compared to the case where the committee is still dependent of the community. The empirical results show that there is a positive influence of decentralized systems governing water allocation on farmers´ productivity. It seems that when the allocation and distribution is managed by the agents who are directly involved in the use of water it may reduce coordination cost. Furthermore, Decentralized systems based only on participation of involved actors would mean not only less coordination costs but more incentives for better management on the sustainability of the system, will give more importance to infrastructure maintenance (as is crucial for water conveyance) and consequently impact positively on better irrigation services by farmers.

It is important to mention however, that the empirical results of this study is only a first approximation for institutional issues affecting water resources use and productive outcomes by farmers. It would be interesting to see this effects controlling for aspects such as irrigation methods and the status of the infrastructure. However, the lack of data available on irrigation for the territory at household level constrained the analysis of this study.

Finally, this paper has shown that the presence of institutions defines the scenario for the access and allocation of water resources in this territory. This scenario ultimately affects farmers' productivity and income. Given the increasing demand for water resources to support agricultural activities in this area, it would be relevant to incorporate policy strategies oriented to improve institutional management of highlands' irrigation systems. Infrastructure provision is important; however, it is relevant to take into consideration the necessity to provide more extension services and technical support aimed at enhancing the institutional framework and managerial decisions by irrigation systems. These strategies may be relevant for better allocation of water resources, sustainability of the system and better irrigation services (proper infrastructure maintenance) for farmers in the highlands.

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APPENDIX: Map of Cuatro Lagunas

The area of study, DTR survey and registered irrigation institutions