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Planting And Harvesting Of Rainwater On Semi-Arid Slopes Of The Sierra And Its Impact On The Process Of Desertification And Climate Change

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Summary
The objective of this article was to carry out the installation of the erosion measurement plots, using the nail method; for which the regions were defined and in each of them the corresponding micro-basins. Likewise, it was also decided to carry out the execution of the infiltration tests, using the method of infiltrometer cylinders, for which the availability of the necessary materials and equipment was evaluated. Among the main findings is that the construction of infiltration ditches on the semi-arid slopes of the mountain range greatly helps the regeneration of the vegetation cover and the hydrological cycle, as well as the recharge of the aquifer through the infiltration of captured rainwater. It is recommended for future research, to carry out at the level of the high Andean highlands the massive construction of infiltration ditches as a practice of water retention on the slopes of the upper and middle parts of the basins.
Keywords: *Water Harvesting, Desertification, Climate Change.*

1. INTRODUCTION

Currently, the world population already exceeds 7,300 million people; of which more than 2 billion live in 50 countries that already suffer from the phenomenon of "water stress" – 1,700 m3/person – year and around 1,200 million of that population suffer from serious water restrictions for their daily survival.- This situation tends to worsen, because by 2050, the world population will be around 9,600 million people, the bulk of the population increase is located in the poorest countries, where water stress will be extremely critical, reason enough for serious social and political conflicts to achieve this vital resource.

In our country, the total population currently exceeds 33 million people and the per capita availability of fresh water is around 71,000 m3/inhabitant-year, a figure that makes our country the 8th place in the world with the highest availability. This situation is really misleading, because on the Peruvian coast – desert area – the per capita availability is currently around 1000 m3/inhabitant-year, a figure lower than the critical limit given by the FAO. This situation is also similar in many areas of the Peruvian highlands, due to the characteristics of semi-aridity and irregularity of the presence of rainfall. especially in the dry months (May – October), despite the fact that in the rainy months (November – April) there is total rainfall between 400 and 1300 mm/year, most of which is quickly lost due to surface runoff and finally stops at sea.

Taking into account that the estimated population of our country in 2050 will be around 43 million people, presenting an increase of around 50% compared to the current population, with the largest proportion of this growth corresponding to the coastal region, consequently the scarcity of water will be accentuated, making the lack of this resource more critical. This whole situation will be further accentuated by the fact that in the middle and upper parts of the basins where rainfall is generated, soil and vegetation resources continue to be degraded, due to water erosion, overgrazing and deforestation, leading these areas to an accelerated process of desertification and its consequent contribution to the process of climate change that has been affecting planet earth as a whole.

Against this backdrop, it is urgent to define a coherent State policy that will allow for the development of concrete and permanent actions in the short, medium and long term in order to help reverse this

process of desertification and to achieve a greater supply of water to meet the growing demand that will arise over the years.
Faced with this gloomy scenario and based on the experiences achieved by different public and private institutions, both national and international, it was planned to carry out the present research work that consists of developing a methodology that allows determining the design characteristics of infiltration ditches as an effective practice for the collection and infiltration of rainwater and the control of water erosion on the slopes of the mountains; as part of a whole system of rainwater harvesting in the upper and middle parts of the high Andean basins, with the purpose of regenerating the hydrological cycle, through reforestation actions, recovery or improvement of pastures and the construction or improvement of small and medium-sized water reservoirs as well as the recharge of groundwater taking advantage of areas of high infiltration capacity or geological faults of the land, with all of which the availability of water in the middle and lower parts of the hydrographic basins can be significantly increased. The implementation of the proposal that is proposed will serve to address the advance of water erosion, desertification and climate change suffered by these areas and consequently will serve as an effective instrument for the fight against poverty of the populations settled in these regions.

2. General objective

Propose planting and harvesting of rainwater on semi-arid slopes of the sierra and its impact on the process of desertification and climate change.

3. METHODOLOGY

The research work was carried out in three stages:

3.1 Planning phase

This phase consisted of the preparation of the work plans for each of the activities to be carried out at both field and cabinet level. Here, based on the objectives set, it was decided to carry out the installation of the erosion measurement plots, using the nail method; for which the regions were defined and in each of them the corresponding micro-basins. Likewise, it was also decided to carry out the execution of the infiltration tests, using the method of infiltrometer cylinders, for which the availability of the necessary materials and equipment was evaluated. In this phase, the different sources where useful information could be obtained for the work to be carried out were also analyzed.

3.2 Field phase

3.2.1 Coordination and awareness-raising activities

As a previous activity to the development of this work, it was necessary to coordinate with the management and technical staff of the Agro Rural Program, in order to be able to achieve logistical and human resources support in the corresponding Regional Directorates and Zonal Agencies. This support was achieved given the affinity of the research work, the objectives and purposes of said institution and the Base Agreement existing between the National Agrarian University "La Molina" and said National Program.
Given the magnitude and importance of the work to be carried out, several trips had to be scheduled to the different Directorates and Zones located in the interior of the country, to achieve the awareness of the officials of these Regions with the objectives of the research work, as well as the establishment in a consensual manner of the technical procedures for the execution of the field tests. chiefly. The field staff of this Program had to internalize the objectives of the work, so that they can decisively help in the performance of the tests and in the care of the material.

3.2.2 Selection of micro-watersheds and location of field areas.

The selection of the micro-basins where the tests were to be carried out was made taking into account the regions and micro-basins where the Agro-Rural Program had been operating, the topographic, soil, climate and representativeness characteristics of the high Andean highlands; as well as the logistical and human support that can be provided for the performance of the fieldwork. Therefore, in summary, the following criteria can be listed, taking into account the selection of the micro-watersheds and the location of the areas where the measurement and infiltration test plots were to be installed:

- That they are located in the high Andean region of Peru, at an altitude equal to or greater than 2,500 meters above sea level.
- That it belongs territorially to a peasant community or peasant organization, which allows it to provide security of the goods and facilitate the use of its lands for the installation of the plots and to carry out field measurements.
- That the selected area is located in an area that has infiltration ditches already built and fully operational, in a minimum area of 0.5 ha. and that these areas are being used. Before the installation of the plots, full rehabilitation was carried out if deemed necessary.
- That they are located in hillside areas, with an average slope of the land between 15% and 70%.
- That its physiography and soil type is representative of the Andean spaces.
- That it has a control area (0.5 ha) adjacent to the area with infiltration ditches, without any treatment and with similar physiographic and edaphic characteristics as the area treated with infiltration ditches.
- That they are not subject to physical alterations caused by anthropic or animal activities.
- That has access to the mobile transport of materials and transfer of personnel, for the timely execution of the tests and the monitoring of the measurements and field visits that have to be carried out.

In each micro-basin, the field area was selected for the installation of the plots for measuring soil erosion and for carrying out the infiltration tests. These areas were georeferenced for a full location. The surface area of these areas was at least 1 ha; taking care that at least 0.5 ha, have infiltration ditches already built and the rest is considered as a control, that is, without any treatment.

3.2.3 Selection of weather stations

In order to determine the maximum rainfall intensities in the mountains, the stations of Weberbauer (Cajamarca), Huancavelica (Huancavelica), Santa Rosa (Ayacucho), Yauricocha (Junín) and Kayra (Cuzco) were selected, from which the rainfall information and hydrological studies developed by different interested institutions were compiled. Based on this, the curves I - D - F were made. For each of the selected stations.

3.2.4 Development of infiltration tests:

The infiltration tests were carried out in the adjoining area, where the erosion plots were installed. The method used to carry out these tests was that of infiltrometer cylinders. In total, 68 infiltration tests and 12 additional tests were carried out in the Ayacucho Region as part of a practical work of the Course of Management and Integral Management of Watersheds, of the Graduate School of the UNALM. The total time of each test was 3 net hours of field readings. All tests were conducted between October 2010 and May 2011.

3.2.5 Survey on the impact of areas treated with infiltration ditches

In order to be able to qualitatively know the impact of infiltration ditches on rainwater harvesting and consequently on the recharge of the underground aquifer, translated into a greater availability of water in the puquios, springs or water springs, especially in the dry season; as well as the impact on pastures and forest plantations, surveys were carried out with the beneficiaries, technicians and professionals who work in the areas near the areas treated with this conservationist practice; and then these surveys are processed using a non-parametric method. The surveyed areas were installed by the ex-PRONAMACHS about 8 years ago on average and are still used to date.

3.3 Cabinet Phases

3.3.1 Determination of infiltration equations

Based on the field information obtained for each of the infiltration tests, the parameters of the Kostiakov equation were determined, in order to determine the relationship between the accumulated infiltrated sheet and the accumulated time. Likewise, for each test, its respective coefficient of determination (r2) was determined, in order to determine the degree of reliability of the equation found. Once this first stage was carried out, 3 large groups of tests were formed with the field data, corresponding to soils with a light, loamy and clayey texture. - Then a general equation was determined for each of the 3 large groups of soils with their respective coefficient of determination. - Based on these equations, the basic infiltration rates can be determined according to the type of soil on the slope where it is decided to build infiltration ditches.

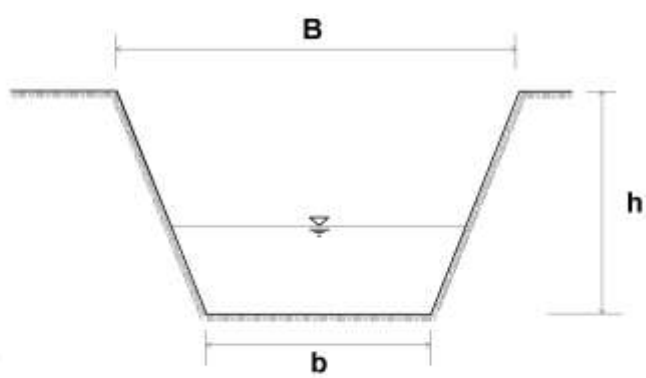
3.3.2 Determination of the Curves I – D – F

Based on the information on the storms from the meteorological stations of Weberbauer (Cajamarca), Huancavelica (Huancavelica), Santa Rosa (Ayacucho), Yauricocha (Huancayo) and Kayra (Cuzco) as well as the review of different hydrological works carried out by the National Program of Small and Medium Irrigations (PRONAPEPMI), during the 70s and 80s; and from some thesis work carried out for these meteorological stations, a graph of Intensity – Duration – Frequency will be obtained in order to define the maximum intensity of precipitation for a duration of 60 minutes and for a return period of 25 years, representative for the critical or most unfavorable conditions that may occur in the mountains; the same that will serve to carry out the simulations in the calculation of the hydraulic characteristics of the infiltration ditches and their recommended spacing between them.

3.3.3 Hydraulic design of infiltration trenches:

The hydraulic design and construction of infiltration ditches must respond to the basic condition that the amount of rainwater that drains from the catchment area, also known as the impluvium zone, must be less than or equal to the amount of water that captures and infiltrates the trench in a given time. That is, the capacity of an infiltration ditch should not be under any justification, less than the total water drained from the surface of the catchment area. To this end, software will be developed to determine the appropriate spacing between infiltration ditches according to the maximum intensity of precipitation in the area and for a duration of 1 hour and for a return period of 25 years; according to the slope of the slope and its corresponding coefficient of surface runoff.

Plan views of an infiltration trench with partitions.



Geometric characteristics of an infiltration trench

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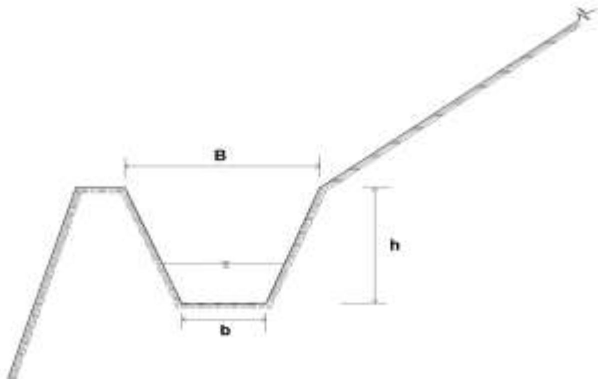

Section of an infiltration trench on a slope

3.3.4 Assessment of the impact of infiltration ditches on rainwater harvesting and vegetation cover:
To quantify the impacts generated by the construction of the infiltration ditches, carried out at least 8 years ago; A format was designed to carry out a survey and achieve the collection of field information, having as informants the beneficiaries of these works, as well as technicians, professionals and local authorities or leaders.
The application of the survey seeks to qualitatively know the possible impacts on the regeneration of the vegetation cover, availability of water in the springs or water holes located in the lower parts of the areas with infiltration ditches; as well as the growth in the grasses and trees of these treated areas and the hydrological behavior of the trench itself, that is, knowing if its storage capacity was adequate or not.
The analysis of the information was carried out using non-parametric methods, for which the size of the sample to be carried out had to be defined; The following formula was used for this purpose:

$$n = \frac{N * Z_{\alpha}^{2} p * q}{d^{2} * (N-1) + Z_{\alpha}^{2} * p * q}$$

where:
N = Total population
Z^2 = 1.962 (if the security is 95%)
p = expected proportion (in this case 50% = 0.50) maximizes the sample size
q = 1 – p (in this case 1-0.50 = 0.50)
d = precision (it could be for example 3%).

4. RESULTS AND DISCUSSION
4.1 Infiltration Assessment
After analyzing each of the infiltration tests carried out, they were grouped into three large groups; those corresponding to soils of medium or loamy texture, heavy and light.
Tables 1, 2 and 3 present the consolidated data of the infiltration tests corresponding to the accumulated infiltrated sheets for each of the three large groups of soils.- Column 1 presents the cumulative times used in each of the tests, noting that the total duration of each test was 3 hours (180 min); in the other columns are presented the sheets of infiltrated water corresponding to each accumulated time and each infiltration test; The last column of the tables shows the average infiltrated sheet, expressed in mm.
The general equation of the accumulated infiltrated lamina found for each group is highly reliable, given its high coefficient of determination (r2) found, whose values appear in each table, together with the respective equation.

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In tables 4, 5, 6; The infiltration rate data for each of the tests is presented. In column 1, the cumulative time values for each of the test measurement points are presented; while the last column presents the average values of the infiltration rate for each of the corresponding times. Based on which the determination was made for each of the 3 groups of soils. - At the bottom of each of the tables, the equation found and its respective coefficient of determination (r2) are presented; From which it can be said that the equations found are highly reliable, since their R2 varies between 0.992 and 0.994.
Figures 1, 2 and 3 show the curves of the average accumulated infiltration sheet and Figures 4, 5 and 6 show the curves of the average infiltration rate of each of the 3 groups of soils.
Based on the equations of the average accumulated infiltrated sheet found for each of the soil groups, the equation of the infiltration velocity corresponding to each of them was determined.
The rate of the basic infiltration rate for each of the 3 groups of soils was determined based on the equations of figures 7, 8 and 9, yielding the following results:

$$ib = 0.100\, m/hour, for\ light\ soils$$
$$ib = 0.040 \frac{m}{hour}, for\ loamy\ soils$$
$$ib = 0.012\, m/hour, for\ heavy\ soils$$

Tables with calculations in the original Spanish language.

Table 1. Infiltrated sheet results – lightly textured floors

Región	HUANCAVELICA	AYACUCHO	ANCASH	AYACUCHO	AYACUCHO	AYACUCHO	AYACUCHO	CAJAMARCA	CAJAMARCA	CAJAMARCA	CAJAMARCA	AREQUIPA	ANCASH
Microcuenca	LLAMAYU (HUACHAPAMPA)	POMATAMBO	SAN LUIS	POMATAMBO	LLUNCUNA (AMARUYOC)	POMATAMBO	7-UNSCH	LA ENCAÑADA	LA ENCAÑADA	GRANDE	LA ENCAÑADA	PINA	SAN LUIS
Tiempo Acumulado (min)	LAMINA ACUMULADA INFILTRADA (mm)												
1	4,0	15,0	5,0	18,0	8,0	10,0	6,0	26,0	25,0	7,0	15,0	8,0	6,0
2	7,0	24,0	9,0	30,0	11,0	15,0	6,0	33,0	35,0	12,0	20,0	16,0	11,0
3	10,0	31,0	10,0	36,0	17,0	22,0	15,0	38,0	40,0	16,0	24,0	24,0	16,0
4	12,0	37,0	12,0	44,0	18,0	25,0	24,0	45,0	47,0	19,0	26,0	29,0	20,0
5	14,0	42,0	15,0	50,0	21,0	28,0	26,0	54,0	52,0	23,0	30,0	34,0	24,0
10	16,0	60,0	27,0	74,0	32,0	41,0	28,0	67,0	69,0	34,0	43,0	53,0	41,5
15	21,0	75,0	36,0	92,0	40,0	51,0	36,0	84,0	83,0	48,0	59,0	70,0	56,0
20	26,0	86,0	44,0	106,0	51,0	62,0	44,0	95,0	95,0	58,0	71,0	74,0	69,0
25	33,0	96,0	58,0	119,0	59,0	70,0	49,0	111,0	109,0	69,0	84,0	88,0	81,0
30	39,0	105,0	60,0	130,0	65,0	80,0	62,0	122,0	124,0	77,0	92,0	102,0	89,0
40	55,0	126,0	74,0	148,0	82,0	99,0	73,0	150,0	154,0	92,0	94,0	126,0	105,0
50	68,0	144,0	84,0	163,0	94,0	113,0	95,0	181,0	179,0	104,0	123,0	149,0	118,0
60	81,0	153,0	94,0	179,0	107,0	125,0	98,0	200,0	202,0	118,0	150,0	171,0	132,0
75	99,0	167,0	102,0	206,0	126,0	146,0	121,0	204,0	208,0	137,0	184,0	196,0	156,0
90	113,0	181,0	120,0	232,0	148,0	165,0	145,0	247,0	247,0	155,0	218,0	216,0	184,0
105	129,0	197,0	136,0	251,0	172,0	185,0	168,0	280,0	283,0	171,0	251,0	232,0	201,0
120	145,0	221,0	152,0	274,0	192,0	219,0		314,0	315,0	189,0	283,0	242,0	217,0
150	177,0	266,0	181,0	304,0	231,0	268,0		359,0	363,0	223,0	340,0	256,0	239,0
180	208,0	307,0	209,0	339,0	264,0	310,0		422,0	425,0	252,0	398,0	266,0	258,0

...Continúa

Región	CUSCO	AREQUIPA	CAJAMARCA	APURIMAC	MOQUEGUA	APURIMAC	ANCASH	AYACUCHO	AYACUCHO	ANCASH	CAJAMARCA	ANCASH	AYACUCHO
Microcuenca	CCATCCA	PINA	GRANDE	PALLCAMAYO	VAGABUNDO	CHALLHUAHUA	UCUCHARURE	8-UNSCH	4-UNSCH	RIO NEGRO	GRANDE	SAN LUIS	9-UNSCH
Tiempo Acumulado (min)	LAMINA ACUMULADA INFILTRADA (mm)												
1	11,0	9,0	8,0	5,0	10,0	3,0	11,0	11,0	13,0	6,0	9,0	9,0	11,0
2	16,0	16,0	11,0	10,0	19,0	4,0	22,0	23,0	21,0	18,0	15,0	18,0	23,0
3	20,0	20,0	13,0	13,0	28,0	9,0	32,0	35,0	25,0	25,0	20,0	25,0	35,0
4	24,0	24,0	17,0	16,0	37,0	11,0	41,0	40,0	30,0	33,0	26,0	31,0	40,0
5	28,0	26,0	20,0	19,0	45,0	14,0	49,0	43,0	36,0	39,0	31,0	37,0	45,0
10	42,0	43,0	32,0	33,0	75,0	25,0	81,0	45,0	41,0	66,0	53,0	62,0	59,0
15	57,0	60,0	43,0	45,0	100,0	35,0	107,0	50,0	49,0	94,0	71,0	82,0	70,0
20	71,0	75,0	55,0	48,0	125,0	48,0	112,0	60,0	59,0	113,0	87,0	97,0	101,0
25	87,0	89,0	65,0	61,0	146,0	57,0	142,0	91,0	80,0	130,0	93,0	127,0	118,0
30	98,0	102,0	75,0	73,0	160,0	65,0	155,0	108,0	97,0	147,0	124,0	150,0	136,0
40	120,0	128,0	94,0	92,0	185,0	84,0	173,0	126,0	118,0	166,0	172,0	184,0	159,0
50	142,0	152,0	114,0	115,0	208,0	100,0	224,0	139,0	134,0	189,0	204,0	209,0	190,0
60	162,0	173,0	138,0	133,0	230,0	119,0	268,0	160,0	162,0	210,0	216,0	252,0	228,0
75	190,0	199,0	170,0	161,0	250,0	145,0	319,0	202,0	197,0	237,0	293,0	300,0	258,0
90	215,0	224,0	198,0	190,0	270,0	163,0	350,0	258,0	228,0	259,0	303,0	332,0	297,0
105	239,0	247,0	225,0	214,0	288,0	180,0	355,0	298,0	284,0	288,0	385,0	356,0	334,0
120	263,0	268,0	252,0	239,0	306,0	201,0	360,0	319,0	336,0	318,0	402,0	371,0	375,0
150		294,0	311,0	282,0	322,0	235,0	366,0	381,0	384,0	379,0	411,0	455,0	410,0
180		320,0	355,0	324,0	337,0	253,0	371,0				434,0	499,0	

...Continúa

Región	AYACUCHO	MOQUEGUA	AMAZONAS	CAJAMARCA	CAJAMARCA	ANCASH	ANCASH	CAJAMARCA	ANCASH **	ANCASH	ANCASH	PROMEDIO DE LAMINA ACUMULAD A Z (mm)
Microcuenca	5-UNSCH	VAGABUNDO	SONCHE	RIO GRANDE	RIO	HUARITAMBO	POMABAMBA	LA ENCAÑADA	UCUCHARURE	POMABAMBA	POMABAMBA	
Tiempo Acumulado (min)	LAMINA ACUMULADA INFILTRADA (mm)											
1	18,0	12,0	15,0	6,0	21,0	12,0	56,0	12,0	22,0	12,0	10,0	13
2	30,0	24,0	30,0	12,0	40,0	25,0	64,0	19,0	40,0	20,0	20,0	21
3	42,0	34,0	43,0	17,0	57,0	36,0	70,0	23,0	54,0	31,0	31,0	28
4	54,0	44,0	56,0	22,0	80,0	47,0	74,0	27,0	69,0	45,0	42,0	35
5	65,0	53,0	68,0	26,0	102,0	59,0	79,0	30,0	80,0	54,0	57,0	41
10	78,0	93,0	118,0	46,0	197,0	102,0	93,0	36,0	121,0	102,0	103,0	63
15	92,0	128,0	166,0	66,0	282,0	148,0	108,0	45,0	152,0	150,0	144,0	84
20	110,0	158,0	206,0	81,0	306,0	183,0	120,0	50,0	170,0	169,0	175,0	99
25	145,0	186,0	244,0	95,0	340,0	217,0	129,0	58,0	171,0	199,0	202,0	116
30	172,0	214,0	274,0	117,0	391,0	242,0	141,0	62,0	188,0	236,0	251,0	133
40	197,0	254,0	314,0	159,0	428,0	312,0	158,0	75,0	200,0	329,0	327,0	160
50	223,0	294,0	352,0	194,0	477,0	371,0	176,0	85,0	211,0	369,0	391,0	186
60	263,0	331,0	382,0	228,0	527,0	421,0	189,0	90,0	225,0	421,0	457,0	211
75	307,0	376,0	423,0	289,0	574,0	496,0	208,0	105,0	230,0	508,0	540,0	244
90	341,0	411,0	461,0	344,0	625,0	561,0	237,0	129,0	237,0	556,0	598,0	275
105	411,0	439,0	491,0	383,0	656,0	616,0	259,0	146,0	244,0	638,0	669,0	305
120	475,0	464,0	516,0	443,0	692,0	658,0	276,0	164,0	256,0	685,0	724,0	337
150	538,0	484,0	549,0	516,0	729,0	775,0	313,0	201,0	261,0	691,0	802,0	380
180		502,0	577,0	562,0		857,0	339,0	239,0	265,0	693,0	916,0	397

Table 2. Infiltration test results – loamy textured soils

Región	AYACUCHO	APURIMAC	ANCASH **	LA LIBERTAD	AYACUCHO	AYACUCHO	ANCASH	AYACUCHO	AYACUCHO	ANCASH	APURIMAC	ANCASH	CAJAMARCA	HUANUCO	ANCASH
Provincia	6-UNSCH	ABANCAY	CARHUAZ		2-UNSCH	1-UNSCH	SIHUAS	3-UNSCH	VILCASHUAMAN	HUARI	ANDAHUAYLAS	CARHUAZ	LA ENCAÑADA		
Microcuenca	Cuenca Alta Allpachaca-INIA	CHALLHUAHUACHO	UCUCHARURE	MOTIL (LABUNDAY)	Canaan Bajo - INIA	Canaan Bajo - INIA	SIHUAS	Canaan Bajo - INIA	POMATAMBO	HUARITAMBO	PALLCAMAYO	AMPU	LA ENCAÑADA	SUPICA (SAN RAFAEL)	USUCUTOSH - CACHIS (CHIQUIAN)
Tiempo Acumulado	LAMINA ACUMULADA INFILTRADA (mm)														
1	35,0	6,0	15,0	4,0	12,6	10,8	3,0	10,8	5,0	3,0	12,0	8,0	1,0	3,0	4,0
2	39,0	7,0	34,0	8,0	25,2	20,8	6,0	22,5	8,0	5,0	15,0	10,0	2,0	6,0	8,0
3	43,0	8,0	44,0	11,0	36,0	29,8	7,0	34,2	10,0	6,0	19,0	13,0	3,0	10,0	12,0
4	47,0	9,0	48,0	13,0	46,8	37,0	8,0	46,0	11,0	7,0	22,0	14,0	4,0	12,0	15,0
5	49,0	10,0	50,0	15,0	54,0	42,5	8,2	54,1	13,0	7,5	26,0	16,0	5,0	15,0	18,0
10	53,0	13,0	60,0	19,0	62,4	49,3	13,9	64,0	20,0	13,0	40,0	21,0	9,0	23,0	27,0
15	56,0	16,0	68,0	23,0	71,4	58,4	20,1	73,1	25,0	19,0	52,0	26,0	12,0	30,0	34,0
20	60,0	19,0	78,0	28,0	79,5	66,5	21,0	80,3	30,0	24,0	64,0	32,0	17,0	36,0	41,0
25	67,0	22,0	87,0	31,0	86,7	76,6	24,8	88,5	36,0	28,0	72,0	37,0	21,0	45,0	48,0
30	75,0	25,0	92,0	33,0	92,1	85,7	27,3	97,6	41,0	33,0	81,0	41,0	24,0	50,0	54,0
40	81,0	30,0	101,0	40,0	99,6	95,0	34,3	109,2	50,0	42,0	93,0	56,0	27,0	65,0	63,0
50	87,0	35,0	109,0	48,0	109,5	103,4	43,0	128,4	57,0	49,0	105,0	70,0	36,0	76,0	72,0
60	96,0	41,0	116,0	53,0	120,5	110,9	48,0	136,7	65,0	57,0	117,0	83,0	44,0	92,0	82,0
75	108,0	50,0	125,0	60,0	136,8	123,2	58,0	147,8	79,0	67,0	126,0	101,0	56,0	97,0	95,0
90	116,0	59,0	132,0	69,0	147,6	132,8	67,0	159,9	89,0	76,0	137,0	116,0	66,0	102,0	110,0
105	131,0	68,0	141,0	79,0	158,7	140,6	70,0	169,2	97,0	85,0	146,0	135,0	73,0	109,0	125,0
120	147,0	76,0	146,0	89,0	164,7	147,5	84,0	178,0	114,0	93,0	156,0	148,0	82,0	117,0	140,0
150	163,0	94,0	150,0	112,0	171,8	153,5	103,0	183,4	132,0	108,0	168,0	174,0	101,0	124,0	164,0
180		111,0	154,0	129,0	177,9	158,7		189,8	156,0	121,0	179,0		117,0	134,0	189,0

** Se elimino de analisis estadistico

Table 3. Infiltration results – textured soils

Región	ANCASH	ANCASH	JUNIN	JUNIN	ANCASH	LA LIBERTAD	CUSCO	HUANUCO	LA LIBERTAD	ANCASH **	LA LIBERTAD	ANCASH
Microcuenca	HUARITAMBO	USUCUTOSH - CACHIS (CHIQUIAN)	CHANCHAS (HUACHAPAMPA)	CHANCHAS (HUACHAPAMPA)	RIO NEGRO	MOTIL (LABUNDAY)	PIURAY CCORIMARCA	CHINCHAS (ALTO MARAÑON)	MOTIL (LABUNDAY)	UCUCHARURE	MOTIL (LABUNDAY)	POMABAMBA (SHUILLA)
Tiempo Acumulado (min)	LAMINA ACUMULADA INFILTRADA (mm)											
1	1,0	2,0	3,0	3,0	2,0	3,0	3,0	4,0	3,0	20,0	3,0	5,0
2	1,5	3,0	5,0	4,0	3,0	5,0	4,0	7,0	4,0	23,0	5,0	6,0
3	2,0	3,2	7,0	5,0	4,0	8,0	5,6	8,0	5,0	28,0	6,0	8,0
4	2,5	3,4	8,0	7,0	5,0	9,0	6,9	9,0	6,0	36,0	7,0	10,0
5	3,0	3,6	9,0	7,0	5,0	10,0	7,9	10,0	7,0	46,0	8,0	13,0
10	3,5	4,0	9,5	8,0	8,0	11,0	8,9	18,0	9,0	53,0	10,0	20,0
15	4,0	4,5	10,0	9,0	10,0	12,0	10,9	19,0	11,0	67,0	12,0	23,0
20	4,5	5,0	10,5	10,0	11,0	13,0	12,9	21,0	13,0	70,0	15,0	25,0
25	5,0	5,5	11,0	10,0	12,0	14,0	13,9	23,0	15,0	72,0	18,0	27,0
30	5,5	6,0	11,5	11,0	14,0	15,0	15,9	24,0	18,0	76,0	19,0	28,0
40	6,0	7,0	12,5	12,0	14,0	17,0	17,9	26,0	20,0	80,0	21,0	30,0
50	6,5	8,0	13,5	12,0	14,0	19,0	19,9	28,0	22,0	83,0	24,0	32,0
60	7,0	9,0	14,5	14,0	14,0	20,0	21,9	30,0	24,0	85,0	26,0	35,0
75	7,5	10,0	15,5	16,0	14,0	25,0	24,9	34,0	27,0	89,0	29,0	38,0
90	8,0	11,0	16,5	18,0	14,0	27,0	28,9	36,0	30,0	91,0	32,0	41,0
105	8,5	14,0	17,5	20,0	17,0	31,0	32,9	40,0	33,0	92,0	36,0	44,0
120	9,0	15,0	18,5	22,0	22,0	35,0	36,9	42,0	36,0	93,0	40,0	47,0
150	9,5		20,5	24,0	30,0	43,0	42,9	47,0	45,0	95,0	49,0	53,0
180			22,5	26,0	36,0	49,0			53,0	96,0	57,0	60,0

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Región	ANCASH	HUANUCO	ANCASH	HUANUCO	JUNIN	CAJAMARCA	AMAZONAS	HUANUCO	CAJAMARCA	ANCASH	PROMEDIO DE LAMINA ACUMULADA Z (mm)
Microcuenca	RIO NEGRO	SUPICA (SAN RAFAEL)	POMABAMBA (SHUILLA)	CHINCHAS (ALTO MARAÑON)	CHANCHAS (HUACHAPAMPA)	LA ENCAÑADA	JUCUSBAMBA	SUPICA (SAN RAFAEL)	LA ENCAÑADA	HUARITAMBO	
Tiempo Acumulado (min)	LAMINA ACUMULADA INFILTRADA (mm)										
1	6,0	1,0	9,0	4,0	4,0	1,0	2,0	1,0	2,0	1,0	3,8
2	9,0	2,0	14,0	5,0	6,0	2,0	4,0	2,0	3,0	2,0	5,4
3	12,0	3,0	16,0	6,0	7,0	3,0	6,0	3,0	4,0	3,0	6,9
4	16,0	4,0	18,0	7,0	9,0	4,0	8,0	4,0	5,0	4,0	8,6
5	17,0	5,0	21,0	8,0	11,0	5,0	10,0	5,0	8,0	5,0	10,2
10	25,0	7,0	27,0	10,0	16,0	7,0	18,0	6,0	12,0	10,0	13,7
15	31,0	9,0	36,0	13,0	20,0	10,0	22,0	8,0	15,0	15,0	16,9
20	35,0	11,0	43,0	15,0	25,0	12,0	26,0	14,0	18,0	20,0	19,5
25	40,0	13,0	48,0	17,0	27,0	14,0	31,0	16,0	21,0	25,0	21,7
30	42,0	15,0	48,0	20,0	31,0	15,0	33,0	19,0	27,0	30,0	23,8
40	42,0	18,0	48,0	23,0	37,0	17,0	36,0	20,0	33,0	40,0	26,2
50	42,0	20,0	48,0	28,0	41,0	20,0	40,0	22,0	39,0	50,0	28,7
60	42,0	23,0	59,0	33,0	45,0	24,0	42,0	24,0	45,0	60,0	31,7
75	42,0	25,0	65,0	40,0	50,0	30,0	45,0	28,0	52,0	67,0	35,2
90	42,0	27,0	76,0	45,0	55,0	33,0	48,0	36,0	60,0	74,0	38,6
105	52,0	29,0	83,0	50,0	57,0	37,0	49,0	45,0	69,0	81,0	42,6
120	59,0	31,0	88,0	55,0	59,0	42,0	50,0	56,0	77,0	87,0	46,4
150	75,0	33,0	91,0	67,0	71,0	52,0	54,0	71,0	88,0	91,0	54,9
180	89,0	46,0	99,0	78,0	80,0	61,0	57,0		98,0		63,0

Región	HUANCAVELICA	AYACUCHO	ANCASH	AYACUCHO	AYACUCHO	AYACUCHO	AYACUCHO	CAJAMARCA	CAJAMARCA	CAJAMARCA	CAJAMARCA	AREQUIPA	ANCASH
Microcuenca	LLAMAYU (HUACHAPAMPA	POMATAMBO	SAN LUIS	POMATAMBO	LLUNCUNA	POMATAMBO	7-UNSCH	LA ENCAÑADA	LA ENCAÑADA	GRANDE	LA ENCAÑADA	PINA	SAN LUIS
Tiempo Acumulado (min)	VELOCIDAD DE INFILTRACION INSTANTANEA (mm/min)												
1	4,0	15,0	5,0	18,0	8,0	10,0	6,0	26,0	25,0	7,0	15,0	8,0	6,0
2	3,5	12,0	4,5	15,0	5,5	7,5	3,0	16,5	17,5	6,0	10,0	8,0	5,5
3	3,3	10,3	3,3	12,0	5,7	7,3	5,0	12,7	13,3	5,3	8,0	8,0	5,3
4	3,0	9,3	3,0	11,0	4,5	6,3	6,0	11,3	11,8	4,8	6,5	7,3	5,0
5	2,8	8,4	3,0	10,0	4,2	5,6	5,2	10,8	10,4	4,6	6,0	6,8	4,8
10	1,6	6,0	2,7	7,4	3,2	4,1	2,8	6,7	6,9	3,4	4,3	5,3	4,2
15	1,4	5,0	2,4	6,1	2,7	3,4	2,4	5,6	5,5	3,2	3,9	4,7	3,7
20	1,3	4,3	2,2	5,3	2,6	3,1	2,2	4,8	4,8	2,9	3,6	3,7	3,5
25	1,3	3,8	2,3	4,8	2,4	2,8	2,0	4,4	4,4	2,8	3,4	3,5	3,2
30	1,3	3,5	2,0	4,3	2,2	2,7	2,1	4,1	4,1	2,6	3,1	3,4	3,0
40	1,4	3,2	1,9	3,7	2,1	2,5	1,8	3,8	3,9	2,3	2,4	3,2	2,6
50	1,4	2,9	1,7	3,3	1,9	2,3	1,9	3,6	3,6	2,1	2,5	3,0	2,4
60	1,4	2,6	1,6	3,0	1,8	2,1	1,6	3,3	3,4	2,0	2,5	2,9	2,2
75	1,3	2,2	1,4	2,7	1,7	1,9	1,6	2,7	2,8	1,8	2,5	2,6	2,1
90	1,3	2,0	1,3	2,6	1,6	1,8	1,6	2,7	2,7	1,7	2,4	2,4	2,0
105	1,2	1,9	1,3	2,4	1,6	1,8	1,6	2,7	2,7	1,6	2,4	2,2	1,9
120	1,2	1,8	1,3	2,3	1,6	1,8		2,6	2,6	1,6	2,4	2,0	1,8
150	1,2	1,8	1,2	2,0	1,5	1,8		2,4	2,4	1,5	2,3	1,7	1,6
180	1,2	1,7	1,2	1,9	1,5	1,7		2,3	2,4	1,4	2,2	1,5	1,4

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Región	CUSCO	AREQUIPA	CAJAMARCA	APURIMAC	MOQUEGUA	APURIMAC	ANCASH	AYACUCHO	AYACUCHO	ANCASH	CAJAMARCA	ANCASH	AYACUCHO
Microcuenca	CCATCCA	PINA	GRANDE	PALLCAMAYO	VAGABUNDO	CHALLHUAHUACHO	UCUCHARURE	8-UNSCH	4-UNSCH	RIO NEGRO	GRANDE	SAN LUIS	9-UNSCH
Tiempo Acumulado (min)	VELOCIDAD DE INFILTRACION INSTANTANEA (mm/min)												
1	11,0	9,0	8,0	5,0	10,0	3,0	11,0	11,0	13,0	6,0	9,0	9,0	11,0
2	8,0	8,0	5,5	5,0	9,5	2,0	11,0	11,5	10,5	9,0	7,5	9,0	11,5
3	6,7	6,7	4,3	4,3	9,3	3,0	10,7	11,7	8,3	8,3	6,7	8,3	11,7
4	6,0	6,0	4,3	4,0	9,3	2,8	10,3	10,0	7,5	8,3	6,5	7,8	10,0
5	5,6	5,2	4,0	3,8	9,0	2,8	9,8	8,6	7,2	7,8	6,2	7,4	9,0
10	4,2	4,3	3,2	3,3	7,5	2,5	8,1	4,5	4,1	6,6	5,3	6,2	5,9
15	3,8	4,0	2,9	3,0	6,7	2,3	7,1	3,3	3,3	6,3	4,7	5,5	4,7
20	3,6	3,8	2,8	2,4	6,3	2,4	5,6	3,0	3,0	5,7	4,4	4,9	5,1
25	3,5	3,6	2,6	2,4	5,8	2,3	5,7	3,6	3,2	5,2	3,7	5,1	4,7
30	3,3	3,4	2,5	2,4	5,3	2,2	5,2	3,6	3,2	4,9	4,1	5,0	4,5
40	3,0	3,2	2,4	2,3	4,6	2,1	4,3	3,2	3,0	4,2	4,3	4,6	4,0
50	2,8	3,0	2,3	2,3	4,2	2,0	4,5	2,8	2,7	3,8	4,1	4,2	3,8
60	2,7	2,9	2,3	2,2	3,8	2,0	4,5	2,7	2,7	3,5	3,6	4,2	3,8
75	2,5	2,7	2,3	2,1	3,3	1,9	4,3	2,7	2,6	3,2	3,9	4,0	3,4
90	2,4	2,5	2,2	2,1	3,0	1,8	3,9	2,9	2,5	2,9	3,4	3,7	3,3
105	2,3	2,4	2,1	2,0	2,7	1,7	3,4	2,8	2,7	2,7	3,7	3,4	3,2
120	2,2	2,2	2,1	2,0	2,6	1,7	3,0	2,7	2,8	2,7	3,4	3,1	3,1
150		2,0	2,1	1,9	2,1	1,6	2,4	2,5	2,6	2,5	2,7	3,0	2,7
180		1,8	2,0	1,8	1,9	1,4	2,1				2,4	2,8	

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Table 4. Infiltration rate results – lightly textured soils

Región	AYACUCHO	MOQUEGUA	AMAZONAS	CAJAMARCA	CAJAMARCA	ANCASH	ANCASH	CAJAMARCA	ANCASH **	ANCASH	ANCASH	PROMEDIO DE VELOCIDAD DE INFILTRACION VI (mm/min)
Microcuenca	5-UNSCH	VAGABUNDO	SONCHE	RIO GRANDE	RIO GRANDE	HUARITAMBO	POMABAMBA (SHUILLA)	LA ENCAÑADA	UCUCHARURE	POMABAMBA (SHUILLA)	POMABAMBA (SHUILLA)	
Tiempo Acumulado (min)	VELOCIDAD DE INFILTRACION INSTANTANEA (mm/min)											
1	18,0	12,0	15,0	6,0	21,0	12,0	56,0	12,0	22,0	12,0	10,0	12,6
2	15,0	12,0	15,0	6,0	20,0	12,5	32,0	9,5	20,0	10,0	10,0	10,4
3	14,0	11,3	14,3	5,7	19,0	12,0	23,3	7,7	18,0	10,3	10,3	9,3
4	13,5	11,0	14,0	5,5	20,0	11,8	18,5	6,8	17,3	11,3	10,5	8,7
5	13,0	10,6	13,6	5,2	20,4	11,8	15,8	6,0	16,0	10,8	11,4	8,2
10	7,8	9,3	11,8	4,8	19,7	10,2	9,3	3,6	12,1	10,2	10,3	6,3
15	6,1	8,5	11,1	4,4	18,8	9,9	7,2	3,0	10,1	10,0	9,6	5,6
20	5,5	7,9	10,3	4,1	15,3	9,2	6,0	2,5	8,5	8,5	8,8	4,9
25	5,8	7,4	9,8	3,8	13,6	8,7	5,2	2,3	6,8	8,0	8,1	4,6
30	5,7	7,1	9,1	3,9	13,0	8,1	4,7	2,1	6,3	7,9	8,4	4,4
40	4,9	6,4	7,9	4,0	10,7	7,8	4,0	1,9	5,0	8,2	8,2	4,0
50	4,5	5,9	7,0	3,9	9,5	7,4	3,5	1,7	4,2	7,4	7,8	3,7
60	4,4	5,5	6,4	3,8	8,8	7,0	3,2	1,5	3,8	7,0	7,6	3,5
75	4,1	5,0	5,6	3,9	7,7	6,6	2,8	1,4	3,1	6,8	7,2	3,3
90	3,8	4,6	5,1	3,8	6,9	6,2	2,6	1,4	2,6	6,2	6,6	3,1
105	3,9	4,2	4,7	3,6	6,2	5,9	2,5	1,4	2,3	6,1	6,4	2,9
120	4,0	3,9	4,3	3,7	5,8	5,5	2,3	1,4	2,1	5,7	6,0	2,8
150	3,6	3,2	3,7	3,4	4,9	5,2	2,1	1,3	1,7	4,6	5,3	2,5
180		2,8	3,2	3,1		4,8	1,9	1,3	1,5	3,9	5,1	2,2

Región	ANCASH	ANCASH	JUNIN	JUNIN	ANCASH	LA LIBERTAD	CUSCO	HUANUCO	LA LIBERTAD	ANCASH	LA LIBERTAD	ANCASH **
Microcuenca	HUARITAMBO	USUCUTOSH - CACHIS (CHIQUIAN)	CHANCHAS (HUACHAPAMPA)	CHANCHAS (HUACHAPAMPA)	RIO NEGRO	MOTIL (LABUNDAY)	PIURAY CCORIMARCA	CHINCHAS (ALTO MARAÑON)	MOTIL (LABUNDAY)	UCUCHARURE	MOTIL (LABUNDAY)	POMABAMBA (SHUILLA)
Tiempo Acumulado (min)	VELOCIDAD DE INFILTRACION INSTANTANEA (mm/min)											
1	1,0	2,0	3,0	3,0	2,0	3,0	3,0	4,0	3,0	20,0	3,0	5,0
2	0,8	1,5	2,5	2,0	1,5	2,5	2,0	3,5	2,0	11,5	2,5	3,0
3	0,7	1,1	2,3	1,7	1,3	2,7	1,9	2,7	1,7	9,3	2,0	2,7
4	0,6	0,8	2,0	1,8	1,3	2,3	1,7	2,3	1,5	9,0	1,8	2,5
5	0,6	0,7	1,8	1,4	1,0	2,0	1,6	2,0	1,4	9,2	1,6	2,6
10	0,4	0,4	1,0	0,8	0,8	1,1	0,9	1,8	0,9	5,3	1,0	2,0
15	0,3	0,3	0,7	0,6	0,7	0,8	0,7	1,3	0,7	4,5	0,8	1,5
20	0,2	0,3	0,5	0,5	0,6	0,7	0,6	1,1	0,7	3,5	0,8	1,3
25	0,2	0,2	0,4	0,4	0,5	0,6	0,6	0,9	0,6	2,9	0,7	1,1
30	0,2	0,2	0,4	0,4	0,5	0,5	0,5	0,8	0,6	2,5	0,6	0,9
40	0,2	0,2	0,3	0,3	0,4	0,4	0,4	0,7	0,5	2,0	0,5	0,8
50	0,1	0,2	0,3	0,2	0,3	0,4	0,4	0,6	0,4	1,7	0,5	0,6
60	0,1	0,2	0,2	0,2	0,2	0,3	0,4	0,5	0,4	1,4	0,4	0,6
75	0,1	0,1	0,2	0,2	0,2	0,3	0,3	0,5	0,4	1,2	0,4	0,5
90	0,1	0,1	0,2	0,2	0,2	0,3	0,3	0,4	0,3	1,0	0,4	0,5
105	0,1	0,1	0,2	0,2	0,2	0,3	0,3	0,4	0,3	0,9	0,3	0,4
120	0,1	0,1	0,2	0,2	0,2	0,3	0,3	0,4	0,3	0,8	0,3	0,4
150	0,1		0,1	0,2	0,2	0,3	0,3	0,3	0,3	0,6	0,3	0,4
180			0,1	0,1	0,2	0,3			0,3	0,5	0,3	0,3

… Continúa

Table 5. Infiltration rate results – lightly textured soils

Región	ANCASH	HUANUCO	ANCASH	HUANUCO	JUNIN	CAJAMARCA	AMAZONAS	HUANUCO	CAJAMARCA	ANCASH	PROMEDIO DE VELOCIDAD DE INFILTRACION VI (mm/min)
Microcuenca	RIO NEGRO	SUPICA (SAN RAFAEL)	POMABAMBA (SHUILLA)	CHINCHAS (ALTO MARAÑON)	CHANCHAS (HUACHAPAMPA)	LA ENCAÑADA	JUCUSBAMBA	SUPICA (SAN RAFAEL)	LA ENCAÑADA	HUARITAMBO	
Tiempo Acumulado (min)	VELOCIDAD DE INFILTRACION INSTANTANEA (mm/min)										
1	6,0	1,0	9,0	4,0	4,0	1,0	2,0	1,0	2,0	1,0	3,8
2	4,5	1,0	7,0	2,5	3,0	1,0	2,0	1,0	1,5	1,0	2,7
3	4,0	1,0	5,3	2,0	2,3	1,0	2,0	1,0	1,3	1,0	2,3
4	4,0	1,0	4,5	1,8	2,3	1,0	2,0	1,0	1,3	1,0	2,1
5	3,4	1,0	4,2	1,6	2,2	1,0	2,0	1,0	1,6	1,0	2,0
10	2,5	0,7	2,7	1,0	1,6	0,7	1,8	0,6	1,2	1,0	1,4
15	2,1	0,6	2,4	0,9	1,3	0,7	1,5	0,5	1,0	1,0	1,1
20	1,8	0,6	2,2	0,8	1,3	0,6	1,3	0,7	0,9	1,0	1,0
25	1,6	0,5	1,9	0,7	1,1	0,6	1,2	0,6	0,8	1,0	0,9
30	1,4	0,5	1,6	0,7	1,0	0,5	1,1	0,6	0,9	1,0	0,8
40	1,1	0,5	1,2	0,6	0,9	0,4	0,9	0,5	0,8	1,0	0,7
50	0,8	0,4	1,0	0,6	0,8	0,4	0,8	0,4	0,8	1,0	0,6
60	0,7	0,4	1,0	0,6	0,8	0,4	0,7	0,4	0,8	1,0	0,5
75	0,6	0,3	0,9	0,5	0,7	0,4	0,6	0,4	0,7	0,9	0,5
90	0,5	0,3	0,8	0,5	0,6	0,4	0,5	0,4	0,7	0,8	0,4
105	0,5	0,3	0,8	0,5	0,5	0,4	0,5	0,4	0,7	0,8	0,4
120	0,5	0,3	0,7	0,5	0,5	0,4	0,4	0,5	0,6	0,7	0,4
150	0,5	0,2	0,6	0,4	0,5	0,3	0,4	0,5	0,6	0,6	0,4
180	0,5	0,3	0,6	0,4	0,4	0,3	0,3		0,5		0,3

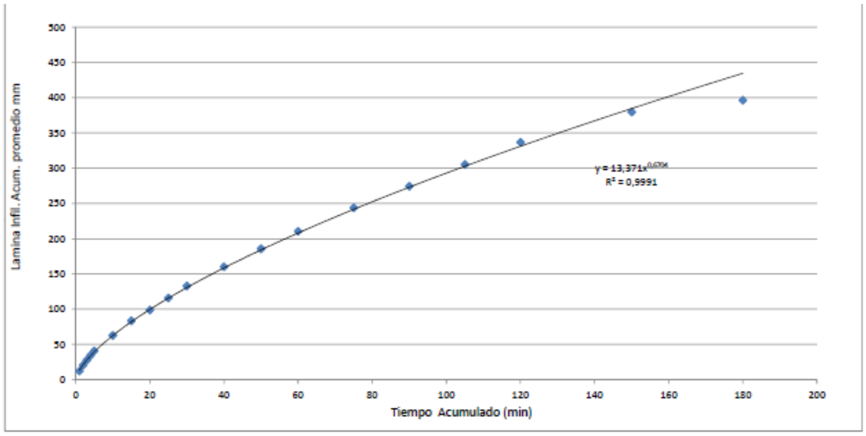

Figure 1. Curve of the average accumulated infiltrated sheet – lightly textured soils. In original language Spanish

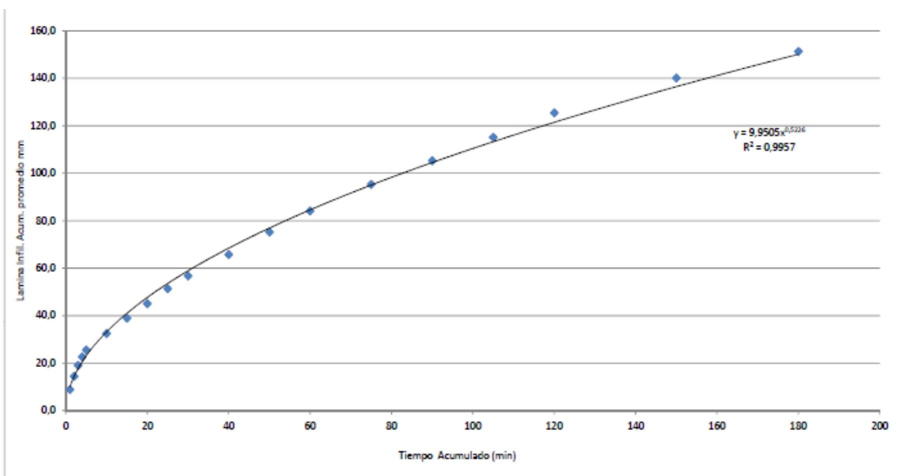

Figure 2. Curve of the accumulated infiltrated sheet – loamy textured soils. In original language Spanish

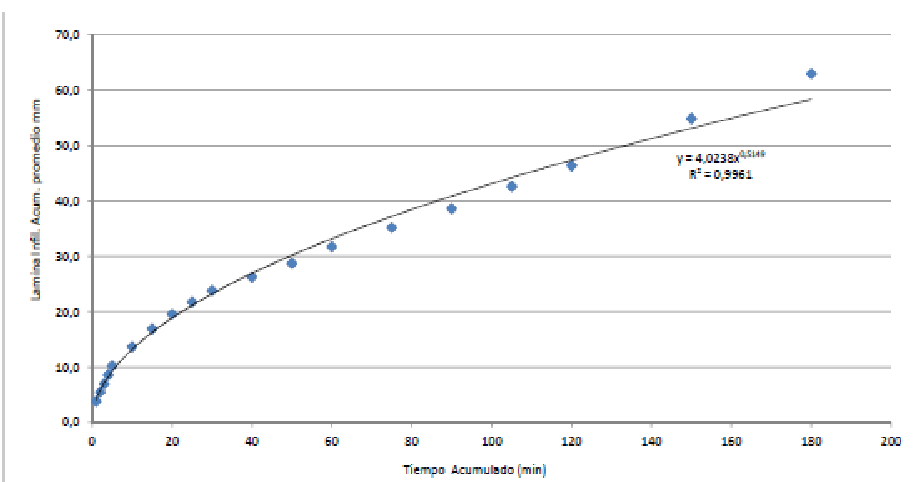

Figure 3. Curve of the accumulated infiltrated sheet – soils with heavy texture. In original language Spanish

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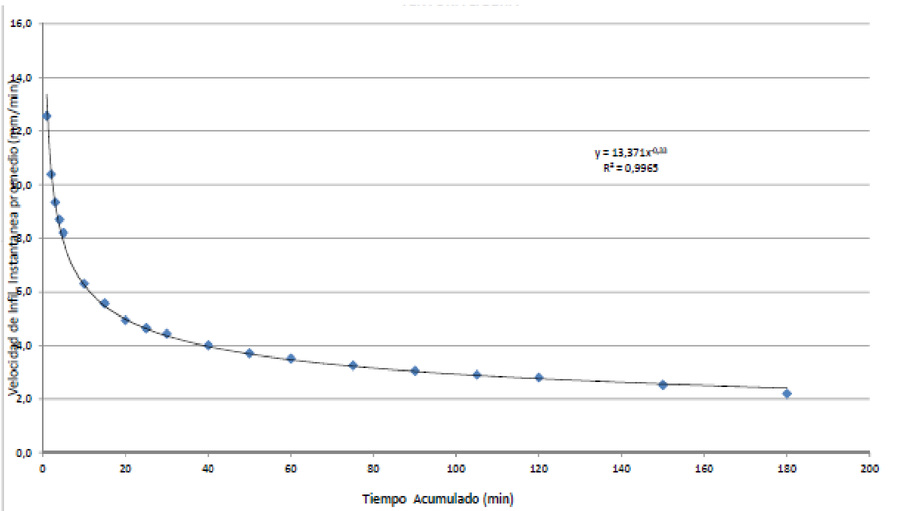

Figure 4. Average instantaneous infiltration rate curve – lightly textured soils. In original language Spanish

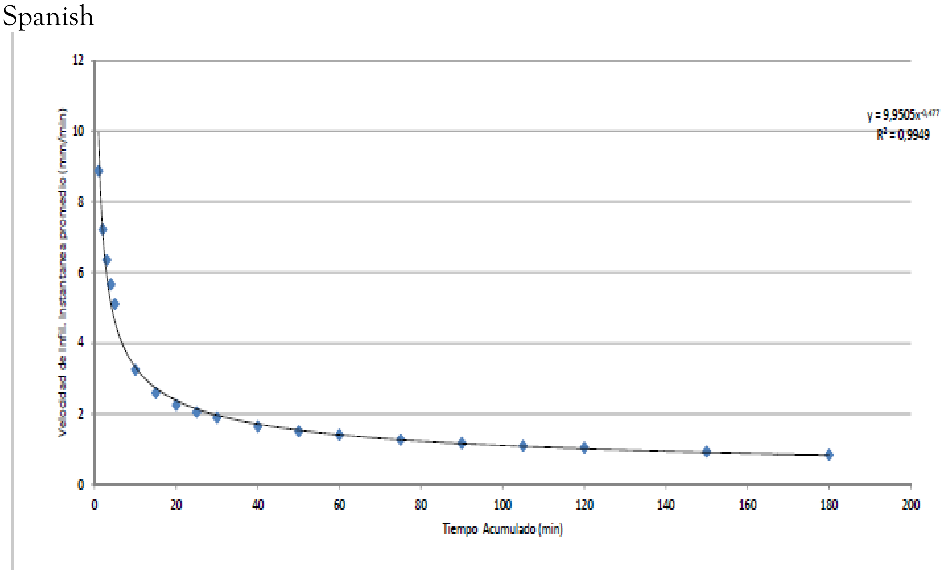

Figure 5. Average instantaneous infiltration rate curve – loamy textured soils. In original language Spanish

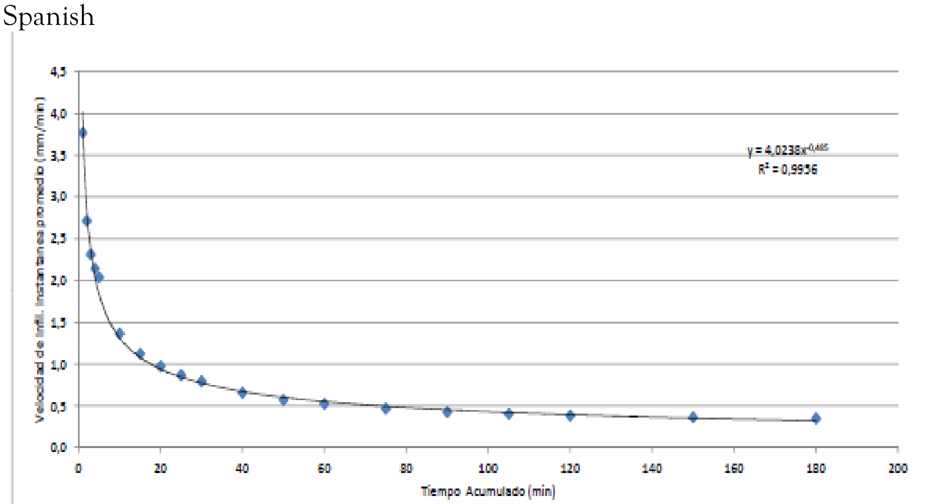

Figure 6. Average instantaneous infiltration rate curve – textured soils. In original language Spanish

4.2 Effect of Infiltration Trenches on Water Regulation

The amount of water infiltrated into the soil will depend on the precipitation characteristics of the physical characteristics of the soil, the spacing between trenches, the infiltration section of the trench and the existing vegetation cover.

When it comes to areas with high runoff coefficients (0.6 to 0.90), that is, when water drains quickly towards the lower part of the basin, it is mainly due to the fact that the soil surface is completely uncovered and the slopes have high slopes; here infiltration is extremely scarce. Under these conditions, it is essential that the rapid surface runoff of water is prevented through water and soil conservation practices, such as infiltration ditches, absorption terraces, afforestation actions, installation of pastures and the consequent regeneration of vegetation cover.

When it comes to areas with pastures, forests, silvopastoral systems or low slopes of the land, the runoff coefficient is relatively low (0.3 – 0.5), here there is a significant retention and infiltration of the water that falls during the rain.

When it comes to light-textured (sandy) soils, the infiltration rate is much higher than in a soil with a heavy texture (clay). Likewise, when it comes to infiltration ditches, the area or section of infiltration of the trench is important, as well as the area or surface of evaporation of the water captured in the infiltration ditch.

Table 6 presents a summary of a simulation of a water balance for a slope with different situations of trench spacing, width of the upper edge of the trench, precipitation characteristics of the area and for a given runoff coefficient. Here the table shows the amounts of water that could infiltrate through the construction of infiltration ditches, being highly significant and important the volumes of water infiltrated in the areas with the highest runoff coefficient, that is, in areas with scarce vegetation cover either due to overgrazing or deforestation, which will undoubtedly help the regeneration of the vegetation cover on these slopes; that if not captured and infiltrated, will quickly drain into the streams and rivers.

Table 6.- Estimated volume of infiltrated water (m3/ha) through the infiltration ditches.
Evaporation = 6.00 mm/day Evaporation time = 180 days

Precipitation (mm/year)	**Trench spacingd (m)**	**Ce = 0.3**		**Ce = 0.5**		**Ce = 0.7**		**Ce = 0.9**	
		B = 0.7 (m)	**B = 1.20 (m)**	**B = 0.70 (m)**	**B = 1.20 (m)**	**B = 0.7 (m)**	**B = 1.20 (m)**	**B = 0.70 (m)**	**B = 1.20 (m)**
600	5	280	(-)	1400	408	2680	1600	3800	2800
	10	1000	504	2200	1700	3400	3900	4600	4100
	15	1300	1000	2500	2100	3700	3300	4900	4500
	20	1400	1100	2600	2300	3800	3550	5000	4700
800	5	800	(-)	2400	1400	4000	300	5600	4600
	10	1600	1100	3200	2700	4800	4300	6400	5900
	15	1900	1500	3450	3100	5100	4700	6650	6300
	20	2000	1700	3600	3350	5200	4950	6800	6500

Example: For a rainfall of 800 mm/year
Ce = 0.30
B = 0.70 m
D = 10 m
∴ Infiltrated vol. = 1600 m3/ha through the trench

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Ficha Técnica Nº	FECHA	IRECCION RURA	AGENCIA ZONAL	Area de Evaluación Has.	Longitud Total de Zanjas (m)	Pregunta Nº														
						6									7			8		
						Pastos			Arboles			Cultivos								
						B	R	M	B	R	M	B	R	M	B	R	M	B	R	M
1	13/09/2011	Cajamarca	Cajabamba - San Marcos	12,00	6000,00		1						1		1			1		
2	13/09/2011	Cajamarca	Cajabamba - San Marcos	20,00	10000,00		1								1			1		
3	13/09/2011	Cajamarca	Cajabamba - San Marcos	10,00	5000,00		1						1		1			1		
4	13/09/2011	Cajamarca	Cajabamba - San Marcos	20,00	10000,00		1						1		1			1		
5	13/09/2011	Cajamarca	Cajabamba - San Marcos	8,00	4000,00		1						1		1			1		
6	13/09/2011	Cajamarca	Cajabamba - San Marcos	4,00	8000,00		1						1		1			1		
7	15/09/2011	Cajamarca	Cajamarca	1,50	1000,00	1									1			1		
8	15/09/2011	Cajamarca	Cajamarca	1,50	1000,00				1			1			1			1		
9	15/09/2011	Cajamarca	Cajamarca	2,00	2000,00				1			1			1			1		
10	15/09/2011	Cajamarca	Cajamarca	1,00	200,00				1			1			1			1		
11	15/09/2011	Cajamarca	Cajamarca	3,00	1700,00		1			1					1			1		
12	15/09/2011	Cajamarca	Cajamarca	1,00	400,00				1			1			1			1		
13	13/09/2011	Cajamarca	Chota - Hualgayoc	1,50	100,00		1			1							1	1		
14	13/09/2011	Cajamarca	Chota - Hualgayoc	2,00	400,00		1		1						1			1		
15	13/09/2011	Cajamarca	Chota - Hualgayoc	3,00	1200,00	1									1			1		
16	13/09/2011	Cajamarca	Chota - Hualgayoc	4,00	1600,00	1									1			1		
17	13/09/2011	Cajamarca	Chota - Hualgayoc	2,00	800,00				1						1			1		
18	13/09/2011	Cajamarca	Contumaza Gran Chimú	1,00	485,00					1							1			1
19	13/09/2011	Cajamarca	Contumaza Gran Chimú	2,00	730,00					1							1	1		
20	13/09/2011	Cajamarca	Contumaza Gran Chimú	0,56	225,00		1										1			1
21	13/09/2011	Cajamarca	Contumaza Gran Chimú	1,80	1470,00		1										1			1
22	13/09/2011	Cajamarca	Contumaza Gran Chimú	1,10	880,00		1										1			1
23	13/09/2011	Cajamarca	Contumaza Gran Chimú	0,50	245,00					1							1	1		
24	13/09/2011	Cajamarca	Cutervo	10,00	6000,00		1			1		1			1			1		
25	13/09/2011	Cajamarca	Cutervo	14,00	12000,00		1			1			1		1			1		
26	13/09/2011	Cajamarca	Cutervo	10,00	8000,00		1				1			1	1			1		
27	13/09/2011	Cajamarca	Cutervo	5,00	3000,00		1			1					1			1		
28	13/09/2011	Cajamarca	Cutervo	8,00	4800,00		1			1					1			1		
29	13/09/2011	Cajamarca	Cutervo	20,00	12000,00	1				1					1			1		
30	13/09/2011	Cajamarca	Cutervo	10,00	6000,00		1			1			1		1			1		
31	13/09/2011	Cajamarca	Cutervo	2,00	5000,00		1				1	1			1			1		
32	13/09/2011	Cajamarca	Cutervo	15,00	6000,00	1			1			1			1			1		
33	13/09/2011	Cajamarca	Celendín	0,20	90,00	1									1			1		
34	13/09/2011	Cajamarca	Celendín	0,35	129,00		1			1					1			1		
35	13/09/2011	Cajamarca	Celendín	1,15	420,00		1								1			1		
36	13/09/2011	Cajamarca	Celendín	1,25	278,00	1									1			1		
37	13/09/2011	Cajamarca	Celendín	0,38	129,00				1						1			1		
38	13/09/2011	Cajamarca	Celendín	0,25	194,00		1								1					
39	13/09/2011	Cajamarca	Santa Cruz	1,00	360,00					1					1			1		
40	13/09/2011	Cajamarca	Santa Cruz	1,00	360,00	1			1						1			1		
41	13/09/2011	Cajamarca	Santa Cruz	1,00	400,00					1					1			1		
42	13/09/2011	Cajamarca	Santa Cruz	1,00	400,00					1					1			1		
43	13/09/2011	Cajamarca	Santa Cruz	1,00	400,00					1					1			1		
44	13/09/2011	Cajamarca	Santa Cruz	1,00	380,00					1					1			1		
45	13/09/2011	Cajamarca	San Miguel - San Pablo	1,00	550,00					1					1			1		
46	13/09/2011	Cajamarca	San Miguel - San Pablo	1,00	500,00	1									1			1		
47	13/09/2011	Cajamarca	San Miguel - San Pablo	1,50	800,00		1								1			1		
48	13/09/2011	Cajamarca	San Miguel - San Pablo	1,25	1000,00		1			1			1				1	1		
49	13/09/2011	Cajamarca	San Miguel - San Pablo	0,25	120,00		1			1			1				1	1		
50	13/09/2011	Cajamarca	San Miguel - San Pablo	0,18	140,00		1			1			1				1	1		
51	13/09/2011	Cajamarca	San Miguel - San Pablo	0,50	1,80		1										1	1		
52	13/09/2011	Cajamarca	San Miguel - San Pablo	1,50	600,00		1		1						1			1		
53	13/09/2011	Cajamarca	San Miguel - San Pablo	1,00	500,00		1								1			1		
54	15/06/2011	Huancavelica	Acobamba	1,50	2450,00		1								1			1		
55	16/06/2011	Huancavelica	Acobamba	2,50	2450,00		1								1			1		
56	15/06/2011	Huancavelica	Acobamba	4,00	4120,00		1								1			1		
57	15/06/2011	Huancavelica	Acobamba	20,00	1950,00		1		1						1			1		
58	17/06/2011	Huancavelica	Acobamba	10,00	4280,00		1								1			1		

4.3 Assessing the Impact of Infiltration Ditches on Rainwater Harvesting on Vegetation Cover

The results of the 77 surveys are consolidated in Table 7.

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Table 7. Evaluation of impacts in areas with infiltration ditches.

59	15/06/2011	Huancavelica	Acobamba	5,00	12540,00		1			1					1			1		
60	14/06/2011	Huancavelica	Acobamba	9,00	1980,00		1								1			1		
61	19/09/2011	Huancavelica	Huaytara	200,00	140000,00	1				1					1			1		
62	19/09/2011	Huancavelica	Castrovirreyna	100,00	40000,00	1									1			1		
63	19/09/2011	Huancavelica	Castrovirreyna	920,00	368000,00	1									1			1		
64	19/09/2011	Huancavelica	Castrovirreyna	100,00	40000,00	1									1			1		
65	19/09/2011	Huancavelica	Castrovirreyna	20,00	8000,00	1									1			1		
66	Set-2011	Huancavelica	Tayacaja	5,00	50000,00		1								1			1		
67	Set-2011	Huancavelica	Tayacaja	1,00	10000,00		1								1			1		
68	Set-2011	Huancavelica	Tayacaja	6,00	60000,00		1								1			1		
69	15/09/2011	Lima	Oyon-Huara	35,00	35000,00		1			1					1			1		
70	15/09/2011	Lima	Oyon-Huara	35,00	35000,00		1			1					1			1		
71	15/09/2011	Lima	Oyon-Huara	3,00	1500,00		1			1					1			1		
72	19/09/2011	Lima	Cajabamba - San Marcos	210,00	30000,00	1			1			1				1				
73	15/09/2011	Lima	Oyon-Huara	1,00	450,00					1					1			1		
74	15/09/2011	Lima	Oyon-Huara	3,00	1500,00		1			1					1			1		
75	15/09/2011	Lima	Oyon-Huara	35,00	35000,00	1				1					1			1		
76	15/09/2011	Lima	Oyon-Huara	1,00	450,00				1						1			1		
77	15/09/2011	Lima	Oyon-Huara	35,00	35000,00		1			1					1			1		
				1977,22	1047758,80	16	44	0	13	30	2	8	10	1	65	1	11	71	0	4

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Among the conclusions addressed in this research work are the following:

The average loss of soil due to water erosion on the slopes of the high Andean mountains is quite high, in the order of 45 t/ha-year, which is equivalent to 4,500 t/km2-year or 3.20 mm/year; which is significantly reduced to an average of 24.44 t/ha-year or 2444 t/km2-year (1.73 mm/year) when the slopes are treated with infiltration ditches.

The light-textured (sandy) soils of the high Andean highlands have a representative average equation of the accumulated infiltration of:

Icum = 13.37 t_0^0.570, where Icum = accumulated infiltrated lamina (mm),

TO = Cumulative Infiltration Time (min) and its corresponding coefficient of determination (R2) is: 0.999.

The loamy (medium) textured soils of the high Andean highlands have an average equation representative of the accumulated infiltration of

Icum = 9.950 t_0^0.522 and its coefficient of determination (r2) was 0.995, the equation being highly reliable.

The soils of heavy texture (clay) of the high Andean highlands have a representative average equation of the accumulated infiltrated sheet of: Icum = 4.023 t_0^0.514 and its coefficient of determination (r2) was 0.996, indicating that the equation found is highly reliable.

The basic infiltration rate (ib) found for soils with sandy, loamy and clayey texture are: 0.100 m/hour; 0.040 m/hour and 0.012 m/hour respectively.

The analysis of rainstorms shows that the maximum intensity of precipitation representative for the Peruvian highlands, for a duration of 60 minutes and for a return period of 25 years, is 27.8 mm/hour for the Weberbauer station (Cajamarca); 23.4 mm/hour for the Yauricocha station (Junín); 23.3 mm/hour for Santa Rosa station (Ayacucho); 21.9 mm/hour for the Huancavelica station (Huancavelica) and 12.92 mm/hour for the Kayra station (Cuzco).

The determination of the hydraulic characteristics of the infiltration ditches and the spacing between them can be determined by means of the software: "UNA LA MOLINA INFILTRATION DITCHES", for any terrain condition, whether from the topographic, hydrological, surface runoff and type of soil texture or basic soil infiltration rate.

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The appropriate hydraulic characteristics for manually constructed infiltration ditches are: b = 0.30 m, B = 0.50 m and h = 0.40 m. The recommended trench spacing for these features is about 10 m.
The appropriate hydraulic characteristics for mechanically constructed infiltration ditches are: b = 0.40 to 0.50m, B = 0.60 – 0.80m and h = 0.30 – 0.40m.- The recommended spacing between trenches should not be less than 10m and in the case of pastures, it can be 15 to 20 m of separation between trenches.
The volume of water infiltrated into the infiltration ditches for an average annual rainfall between 600 and 800 mm/year varies between 280 and 6800 m3/ha-year, depending on the spacing between trenches, the width of the upper edge, the characteristics of the precipitation of the area and the coefficient of surface runoff of the slope.
The construction of infiltration ditches on the semi-arid slopes of the mountain range greatly helps the regeneration of the vegetation cover and the hydrological cycle, as well as the recharge of the aquifer through the infiltration of captured rainwater.
The regeneration of the vegetation cover of semi-arid slopes through pastures or forest plantations helps to decontaminate the environment, to combat the desertification process and global warming.
The assive construction of infiltration ditches and the planting of trees and pastures is an effective measure to combat poverty among the populations settled on the high Andean slopes.

5.2 Recommendations

It is recommended to continue with research work of this nature.
The massive construction of infiltration ditches must be carried out at the level of the high Andean highlands as a practice of water retention on the slopes of the upper and middle parts of the basins.

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