Drainage and land reclamation in Peru

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1 Introduction

Peru is a country of 1 285 215 km^2, divided in three natural regions, the Coast, a desert where agriculture is possible only under irrigation; the Sierra, high mountains with sufficient seasonal precipitation for one crop a year, where irrigation is tried as an option for a second crop; and the Jungle, a very humid zone, covered by a dense forest, and hardly used for intensive agricultural purposes. The land use pattern of the Peruvian regions is presented in Table 1.

Table 1 The land use pattern of the Peruvian Regions

Description	Total	Coast	Sierra	Jungle
		(area in 1000 ha)		
Total surface area	128 521	14 400	33 517	80 604
Potential agricultural land	4 887	1 527	1 500	1 860
Land under cultivation	2 442	928	1 200	314
Irrigable land	1 642	1 018	463	161
Land under irrigation	904	647	223	34
Pasture	17 915	1 622	10 576	5 717
Population (June 1986)	20.2 Millions	50%	38%	12%

Although different in characteristics, origin and economic importance, the three regions have drainage problems.

The Coast

The coast has the most important drainage problems to be solved. Most of the problems are associated with soil salinity. Approximately 250 000 ha (30% of the best agricultural land) needs some kind of reclamation work. The origin of the problem is the low irrigation efficiency, the marine origin of the soils and the very low natural drainability of the lowlands.

The Sierra

There are approximately 120 000 ha affected by high watertables, especially on the lower part of the inter-Andean valleys and areas surrounding lakes and lagoons. The solution is usually related to the presence of drainage water disposal facilities.

The Jungle

The best agricultural lands are affected by drainage problems, due to excess precipitation, river floods and flat lands. Until now these lands are cultivated with pasture and rice, without much drainage improvement.

2 Most important drainage and land reclamation projects

Most drainage and land reclamation in Peru is concentrated on the Coast (Figure 1). In 1963 30% of the coastal agricultural lands was estimated to be affected by drainage and salinity problems. In 1976 this figure was estimated at 34%, while in 1986 the estimation was 32% (Table 2).

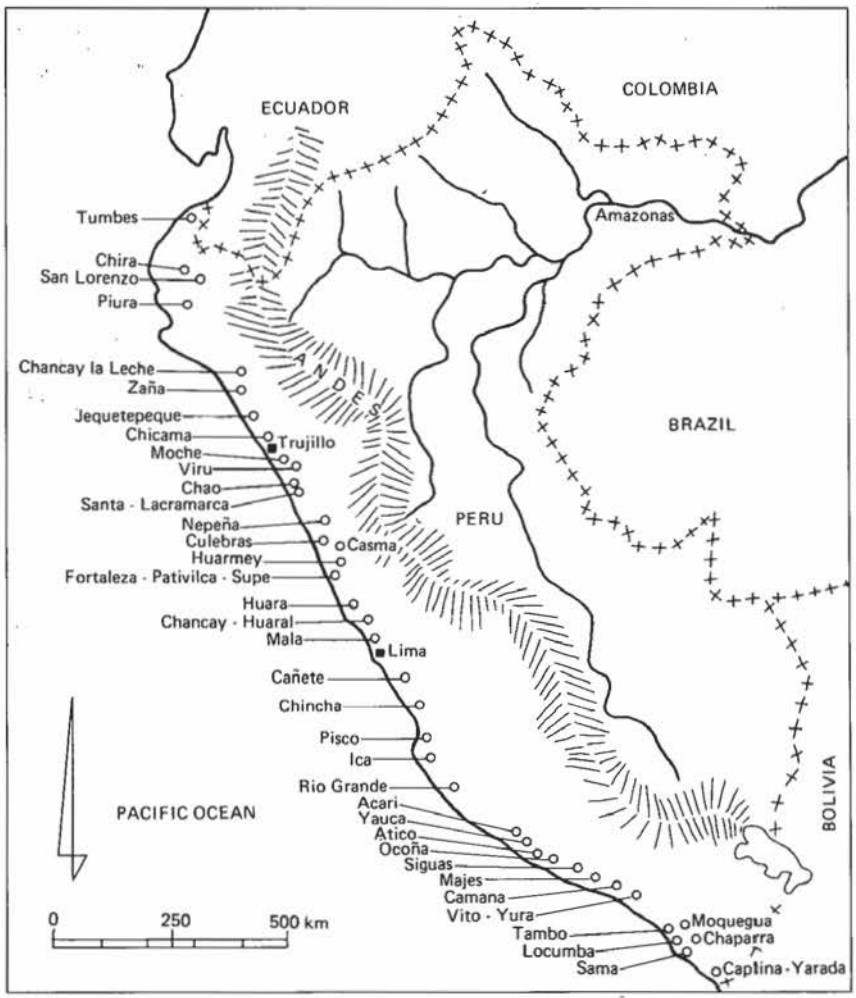

Figure 1 Valleys on the Peruvian coast with drainage and salinity problems

Table 2 Drainage and salinity problems in coastal valleys (ha)

Valley	Total agricultural area	1986 evaluation			
		Light salinity and drainage problems	Moderate salinity problems	Moderate to severe salinity and drainage problems	Total affected area
Tumbes	12 226	1 339	–	7 201	8 540
Chira	33 344	9 103	189	7 550	16 842
Piura (Medio y Bajo)	64 700	15 000	–	10 000	25 000
Alto Piura	46 000	N.D.	N.D.	N.D.	12 000
Col. San Lorenzo	38 000	5 000	3 000	5 000	13 000
Chancay-La Leche	106 299	26 911	166	20 000	47 077
Zaña	18 250	3 685	2 604	1 189	7 478
Jequetepeque	46 996	19 700	526	3 251	23 477
Chicama	71 593	4 428	16 097	5 822	26 347
Moche	10 447	806	1 574	141	2 521
Chao	7 288	–	521	274	795
Virú	11 119	643	2 869	757	4 269
Santa-Lacramarca	17 690	336	2 016	1 240	3 592
Nepeña	10 400	2 100	1 560	120	3 780
Culebras	1 735	380	–	–	380
Casma	13 151	1 150	1 130	900	3 180
Huarmey	2 250	290	490	290	1 070
Fortaleza-Pativilca y Supe	24 430	1 248	15	1 656	2 919
Huaura	37 360	3 420	508	2 052	5 980
Chancay-Huaral	22 600	1 770	610	2 020	4 400
Mala	8 000	–	440	1 150	1 590
Cañete	24 050	816	2 000	–	2 816
Chincha	24 000	–	800	1 460	2 260
Pisco	18 383	5 000	–	2 500	7 500
Ica	32 216	1 195	1 000	375	2 570
Rio Grande	23 876	–	114	66	180
Acari	5 042	–	–	964	964
Yuaca	1 536	218	577	173	968
Chaparra	1 062	N.D.	N.D.	N.D.	110
Atico	140	6	–	–	6
Ocoña	782	370	–	19	389
Camaná	6 003	1 000	200	–	1 200
Majes	6 289	305	–	–	305
Siguas	2 633	277	–	235	512
Vitor	5 562	251	–	879	1 130
Tambo	10 198	–	3 000	–	3 000
Locumba	3 210	N.D.	N.D.	N.D.	3 179
Sama	2 896	–	1 444	1 452	2 896
Moquegua	2 589	–	4	45	289
Caplina-Yarada	7 953	3 500	4 453	–	7 953
Total	782 298				252 464

During the last ten years some projects have been executed and approximately 24 000 ha have been rehabilitated, whereas 16 000 ha are under rehabilitation. Still the total area affected has been reduced only by 2576 ha. The reason for that is an increase of the problems and some deterioration of the existing infrastructure. Recent studies demonstrate that the problems in some areas were under-estimated.

3 Drainage projects under execution

3.1 General

In 1974, a special commission of Peruvian engineers and Dutch technical advisors nominated by the Ministry of Agriculture, formulated the National Plan of Drainage and Land Reclamation along the Coast with recommendations on stages and execution priorities. This was the origin of PLANREHATIC, the government entity responsible for the execution of the National Plan of Drainage and Land Reclamation.

3.2 Main components of rehabilitation plan

- Improvement of the main irrigation infrastructure in the valleys (intakes, channels, measurements, distribution and crossing structures);
- Improvement of the irrigation and drainage infrastructure at farm level in the areas affected by drainage and salinity problems;
- Improvement of the farmers and water users organizations, implementation of a service for technical assistance, especially for operation and maintenance of the infrastructure and improvement of the irrigation efficiency at farm level;
- Provision to the water users of machinery and appropriate workshop for operation and maintenance.

3.3 Rehabilitation stages

3.3.1 Rehatic I

This project was executed between 1974 and 1986 and was partially financed by the World Bank. The total investment was in the order of US$ 47.8 million (28.5 million in works, 3.7 million in machinery and equipment, and 15.6 million for engineering service, supervision and administration). Details of the REHATIC I project are presented in Table 3.

Table 3 Details of the REHATIC I Project

Area (ha)	Mala	Cañete	Pisco	Camaná	Majes	Tambo	Total
Irrigated area	4800	24000	19000	6800	5900	8640	69140
Irrigation improvement	2000	9200	4900	6800	3350	7000	33250
Drainage and reclamation requirements	1250	3695	5370	3017	3350	2374	19056
Field drainage requirement	862	1882	934	918	2384	1403	8383

3.3.2 Rehatic II (Lower Piura)

The lower Piura valley is part of the Chira-Piura Irrigation Project. This valley has a cultivated surface of 50 000 ha. The area affected by drainage and salinity problems is approximately 35 000 ha. As part of the first stage of the Chira-Piura Project, 164 km of main drains have been improved and 97 km of new collector drains have been excavated, and 195 km of existing collectors have been improved. Approximately 25 000 ha are still affected by salinity and drainage problems due to lack of farm drains.

The feasibility study of the remaining area was prepared by REHATIC in 1979. The World Bank gave a loan of approximately US$ 90 million for the construction of the drainage systems. Unfortunately during the execution period (1983), the lower Piura was flooded by very unusual high precipitation, that delayed the execution of the work. At this moment drainage problems still affect 25 000 ha.

3.3.3 Rehatic III

The feasibility study of this stage has been completed by DEPEREHATIC. This project consists of seven small projects: two in the Sierra and five at the Coast. The total irrigated area to be improved is 69 554 ha, of which 49 478 ha need drainage and soil reclamation.

The total investment is in the order of US$ 118.8 million, including US$ 86.6 million for machinery and equipment and US$ 25.8 million for engineering services, administration and supervision.

The report is being reviewed by the World Bank, being interested in partial financing of this project.

The final design prepared by DEPEREHATIC will be completed during 1987.

3.3.4 Other drainage projects

a. Chancay-La Leche (Lambayeque)
   This is a project of 91 600 ha, executed between 1966 and 1980. The drainage and salinity problems in this area affect approximately 30 000 ha. Because of technical, economical and social reasons, this project is considered of first priority. Until now

the main drainage system has been constructed. The subsurface farm drain requirements have been estimated at 4000 km and the total cost at approximately US$ 25 million.

b. Jequetepeque-Saña
This irrigation and drainage improvement project is under execution. According to an evaluation, there are in this zone approximately 6000 ha with drainage problems and 15 000 ha with soil salinity problems due to shortage of irrigation water.

c. Chavimochic project
The main objective of this project under execution is to improve the irrigation water availability by derivation a part of the water from the Santa river. CHAVIMOCHIC is an integrated 4 valley project (Chao, Virú, Moche and Chicama), situated in La Libertad Department, approximately 600 km north of Lima. The actual drainage problems in those valleys affect 12 871 ha. In future with more irrigation, more problems are expected, especially if the present volume of groundwater that is pumped (287 million m^3) will be reduced. Soil salinity affects 21 061 ha, mainly due to lack if irrigation water. The CHAVIMOCHIC project includes improvement of existing drains, excavation of new drains, installation of approximately 1000 km of subsurface drains and yearly replacement of approximately 150 km of old subsurface drains. The most important features of the CHAVIMOCHIC project are presented in Table 4.

Table 4 Pertinent features of the CHAVIMOCHIC project

Area (ha)	Chao	Virú	Moche	Chicama	Total
Total project area	10 668	24 519	15 961	80 600	131 748
Under irrigation	2 000	6 000	8 000	46 000	62 000
Irrigation improvement	5 023	11 625	10 702	65 640	92 990
New land	5 665	12 894	5 259	14 960	38 778
Soil salinity problems	521	2 869	1 574	16 097	21 061
Drainage problems	274	1 400	947	10 250	12 871

4 Drainage technology development

The drainage technology development over the last 20 years is according to the following schedule:

Fase I — Agrarian University, La Molina 1968
– Training — The University with the technical cooperation of the Dutch Government organized a drainage course in Peru, attended by Peruvian engineers.

Fase II — CENDRET 1968-1971
– Training — With technical cooperation of the Dutch Government:

– Research – Basic studies	– Drainage and land reclamation courses were organized, attended by 68 engineers. – Two experimental plots were executed to demonstrate construction procedures, different kind of materials and evaluation of results. – Evaluation of drainage and salinity problems in each valley on the Coast was started.
Fase III – Training – Research – Basic studies – Design and execution of large scale projects	SUDRET 1972-1979 With technical cooperation of the Dutch Government: – Drainage and land reclamation courses were organized attended by 52 engineers. – Two new experimental plots were executed. – San Lorenzo Drainage Project (8300 ha) was projects executed. – Evaluation of drainage and salinity problems in coastal valleys was completed. – PLANREHATIC was started, the study of REHATIC I (6 valleys: 40 000 ha).
Fase IV – Large scale drainage project study – Execution of large scale projects	DEPEREHATIC 1976-1986 With technical and financial cooperation of the Dutch Government. DEPECHP 1980-1986 – Feasibility study, final design and execution of two drainage projects: – REHATIC I (40 000 ha) – REHATIC II (50 000 ha) – Feasibility study of REHATIC III was completed (69 554 ha).

5 Peruvian experience with drainage and land reclamation

Although drainage is an old practice in Peru, until 1986 it was more an empirical practice than a technique, apart from some projects executed by foreign companies. Because of that, drainage projects were usually considered expensive and an uneconomical investment.

As a result of the drainage programme development, Peru has at this moment more than 100 engineers with experience in all the aspects and stages of drainage project development, even though some aspects remain unsolved.

Stocktaking of the qualifications reveals the following:

– Basic studies: there is great experience and capacity;

- Large scale project studies and design: the government and Peruvian private companies have professionals with good experience;
- Work execution: the Peruvian companies have demonstrated great capacity and experience to execute almost total projects. The main constraint is lack of experience to install tile drains at farm level;
- Subsurface drainage: the only large scale project executed was done by a specialized foreign company. No Peruvian company is experienced to do this type of work;
- Supervision: there are enough Peruvian companies and professionals with technical capability to do this job;
- Maintenance: this is one of the main problems without solution. It is basically a problem of proper organization and some administrative and legal regulations;
- Improvement of saline soils: there are enough professionals with experience, but the actual execution is the responsibility of the farmers. Lack of training of farmers causes a delay in the improvement of saline soils.

6 Drainage material and machinery

6.1 Subsurface pipe drains

There is no adequate drain pipe production in Peru. Clay pipe without collar is the most common type of pipe used for farm drainage in Peru. This pipe is not suitable to be installed by a trenching machine, because of unstable soil conditions. In the past years those pipes were installed by hand, but at present it is too slow and costly.

The solution is the use of corrugated plastic pipe, but there is no Peruvian factory interested to produce this pipe. DEPEREHATIC has installed between 1983 and 1985 400 km of corrugated plastic pipe (100 and 65 mm inside diameter and made in Peru), with a machine bought in Europe by a foreign contractor.

Main problems with clay pipes are:

- Very difficult to install correctly in unstable soils (very common in Peru);
- The volume and quality of pipes, produced in Peru, are low (irregular cut and easy to break), making installation by machine problematic;
- The installation by hand is too slow and especially unfavourable in areas under cultivation;
- The width of the excavation at the surface is 6-15 times the width made with a trenching machine, which is unfavourable.

Main problems with concrete pipes are:

- The Peruvian agricultural soils have usually a very high content of calcium sulphate; consequently concrete pipes have to be made with sulphate resistant cement, making the pipe more expensive;
- Because of the thickness of the pipe walls and especially the collar, a wider trench is required;
- The normal length of concrete pipes is one meter, to reduce it to 0.5 m or less will increase drastically the cost;

– The volume of production of this type of pipe is quite low.

6.2 Filter material

The best Peruvian experience in relation to filter material is to use gravel and coarse sand. This type of material exists almost everywhere at very reasonable cost and has been successfully installed by hand and trenching machine.

6.3 Pipe drain collectors

This is not an extensive practice; only concrete pipes have been used until now.

6.4 Drainage machines

a. Trenching machine
   Between 1971 and 1983 Peru purchased five trenching machines in the Netherlands, three of them were bought by the government and two by private companies. All have worked relatively a few hours and are in good working order.
   The main reasons for their limited use are:
   - Difficulty in getting appropriate drain pipes;
   - Difficulty in organizing farm drainage work (economical, social and political aspects);
   - Insufficient budget;
   - Lack of irrigation water for those areas to be reclaimed.

b. Pipe drain cleaning machines
   Five high pressure drain flushing machines have been purchased and are used to clean subsurface farm drain pipes. There are some problems with this practice:
   - Organizational problems cause that the cleaning of the pipe lines is very irregular;
   - Defective drainline installation causes that the cleaning is difficult and sometimes impossible.

c. Ditch cleaning machine
   This operation is usually made with normal retro-excavators, some equipped with a mowing bucket and a cutterbar for reed. A lot of work is still made with hand labour or combined. This cleaning operation is required at least once a year, but because of organizational problems. This is not always fulfilled.

7 Rehabilitation cost

7.1 Investment cost

Drainage projects in Peru are usually related to soil salinity and irrigation problems. Because of that an average of 43% of reclamation investment is used to improve the irrigation system (lining of canals, improvement of intake structures, improvement of groundwater wells and equipment).

The drainage work itself represents approximately 38% of the investment, including main drain systems, farm drains and land preparation for leaching.

The balance of the investment (19%) is used in machinery, equipment and buildings for operation and maintenance. This investment is initially under the responsibility of the project authority and lateron transferred to the water users. A breakdown of the investment costs in drainage projects is presented in Table 5.

Table 5 Typical investment in drainage projects

Type of investment	Area (ha)	Investment $/ha
Irrigation improvement	27900	743
Drainage work	14456	1267
Machinery, buildings and equipment for operation and maintenance	58440	157

7.2 Operation and maintenance

The operation and maintenance of any drainage project is organized at irrigation district level. It is programmed together with the operation and maintenance of the irrigation system.

Peruvian legislation is clear about the responsibilities of each organization. Unfortunately the cooperation and discipline between farmers, water users and governmental organizations is poor. Therefore operation and maintenance is inadequate.

The main problems for adequate operation and maintenance are the lack of sufficient funds and the absence of an authority with more power.

According to the Peruvian law, farmers are obliged to contribute in cash for the total expenses of operation and maintenance. Subsequently they have to be organized in water users associations, but in reality, because of political reasons the farmers contribution is fixed. Due to the inadequate collecting system, only 5 to 10% of the actual cost is collected. As a result there is a gradual deterioration of the drainage works.

There are many studies devoted to the cost of operation and maintenance and the amount to be charged to the farmers. Something has been put into practice, at least for a reasonable time. The political decision to accept exceptions and periodical reductions has weakened the technical requirements.