WATER RESOURCES ALLOCATION AND ENVIRONMENTAL IMPACT ASSESSMENT

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Abstract

The present study deals with the problems resulting from the use of water from the Chiese River along his basin area. It considers the rational scheme for the best allocation of a resource that can be used in different ways and by different users/sectors. Recommendations on the appropriate criteria to be used in alternative projects choice, the proper techniques for designing individual projects and for estimating future project effects have been done.

Résumé

Le travail suivant parle des problèmes qui viennent de l'emploi des eaux du bassin du fleuve Chiese. Le problème fait partie du système rationnel pour la meilleure répartition d'une ressource qui peut être utilisée de différente façon et par différents usagers. On indique quelques suggestions en ce qui concerne les critères les plus convenables de choix parmi des projets alternatifs, les techniques les plus aptes pour définir chaque projet et pour l'évaluation des effets futures qui viennent de la réalisation du projet.

In recent years, the problems of water resource allocation have occupied a central position in the evolution of applied or empirical welfare analysis. Essentially the studies were concerned with a single key question: With the goal of social welfare, what are the processes, the standards, and the criteria which the public decision-maker should apply in forming basic allocation decisions in the water resource field? Consequently, recommendations on the appropriate criteria to be used in alternative projects choice, the proper techniques for designing individual projects and for estimating future project effects have occupied important positions in the discussion.

The present study deals with the problems resulting from the use of water from the Chiese River along his basin area. It considers the rational scheme for the best allocation of a resource that can be used in different ways (i.e.. irrigation, production of hydroelectric power, improvement of the landscape, recreational interests, etc.) and by different users/sectors (farmers, industrial plants, tourism sector, etc.).

It should be mentioned that at the present time, the water flow that can be off taken for irrigation purposes (which is the sum of ancient water rights and later concessions -between 1927-1958) is 32.4 *l*/sec. Since the concessions expired in 1987, the beneficiaries asked for a renewal and at the present time *prorogatio* conditions exist. The water used for irrigation later refills the ground water downhill and can be used once again for irrigation after being brought back to the surface via springs and wells. The Chiese River water off takes influence 31,226 hectares directly and 28,565 hectares indirectly; the affected area includes 59,971 hectares of Agricultural Area. In our study we will consider an area of 31,226 hectares as the Minimum Thesis and 59,971 hectares as the Maximum Thesis. It should also be pointed out that off takes for irrigation and hydroelectric power are possible because the water level in Lake Idro can be regulated allowing a maximum excursion of 7 meters (between level 370 and 363). During the concessions review period the inhabitants of the villages on Lake Idro complained about the damage the fluctuating level caused on the landscape and the environment, and asked for either a reduction or elimination of the allowed excursion. For our purposes, we have simulated the outcomes of different hypotheses or alternatives:

ALT. 0: Represents the current situation which is an artificial range in level of 7 meters in Lake Idro (between level 370 and level 363)

ALT. A: Represents a simulated situation with an artificial range in level of 5 meters in Lake Idro (between level 370 and level 365)

ALT. B: Represents a simulated situation with an artificial range in level of 2.5 meters in Lake Idro (between level 370 and level 367.5)

ALT. C: Represents a simulated situation with no artificial range in level of Lake Idro.

ALT. ENVIRONMENTAL: Represents a simulated situation identical to ALT. C where a shift in tourism supply is considered. The supply is oriented toward a demand which is more sensitive to environmental quality and therefore is willing to pay more.

In this particular case, a survey of the farms has shown, considering different farming system, a gross output per hectare of 11.7 million lire. The cash expenses amounted to 6 million per hectare and therefore added value of 5.7 millions per hectare. The reduction in flow that would derive from each of the alternatives was determined and compared to the threshold flow under which a decline in irrigated surfaces would occur, considering the current off take and distribution of water. For each alternative and for each crop the per hectare damage was calculated in monetary terms. The reduction in gross output, resulting from the reduced availability of irrigation water, determines a decrease of the input demand from the farm sector with a negative impact on the linked sectors.

On the other hand, a decreased usage of Lake Idro as a reservoir would result in less available energy to use in low water periods and a decrease in production for ENEL (Italian acronym of National Electric Power Industry) and other energy producers. Such a decrease was calculated for the different alternatives and compared to Alt. 0. Tourism and recreational activities in lakeside towns would benefit from the decrease or even cancellation of the artificial excursion of the lake's water level. The benefits would arise from a greater inflow of tourists and therefore from increased sales by local businesses. The potential tourism development, which was estimated on the basis of similar experiences, is however, limited by other factors, not linked with the water allocation problem (roads and accommodations in particular). Local businesses (hotels, bed and breakfasts, campgrounds, ect.) were surveyed in order to evaluate the possible sales increase deriving from the implementation of each of the proposed alternatives, excluding Alt. 0.

Comparative economic evaluation of different uses

There are four main actors interested in the utilisation of the Chiese River water for different purposes:

1) Farmers interested in off take for irrigation.

2) Lake shore communities interested in increasing the recreational and environmental value of Lake Idro.

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3) ENEL which uses river water in the Alto Chiese and Vobarno power plants and that complies with the rules established for Lake Idro operation.
4) The private power producers who utilise the water downhill from the Vobarno plant, from the Chiese River and its branches ([1]).
The different uses are competitive or complementary, depending on the type of usage and on the period during which they take place. From a strictly economic perspective, the evaluation should be conducted on the basis of the increases or decreases in value added resulting from the different hypothesis. It should be noted that the value added for a Community is the sum of goods and services the Community produces every year and it is referred to as the gross domestic product.
Increases (+) and decreases (-) in value added for each of the actors interested, expressed in millions of lire, are shown in **tables 1** and **2**.
It is clear that any of the alternatives different from the current situation results in a decrease in value added for the community as a whole. The improvement of tourist activities along the lake's shores that could derive from the decrease or cancellation of excursion levels in Lake Idro water levels does not make up for the loss which would occur for all the other subjects involved (farmers, agricultural input companies that provide technical support to the farmers, ENEL and private energy producers). The negative balance worsens going from ALT. A to B, C, and ENVIRONMENTAL.
The differences in value added losses and gains is greater if the Maximum Thesis is considered. Such thesis takes into account the entire area that benefits from the Chiese waters and not only the one pertaining to the currently existing Alto Chiese and Alto Mantovano irrigation boards. For this thesis, the increases and decreases in value added expressed in millions of lira are shown in **table 2**.

Table 1 ***Minimum thesis.***

	Alt. A	Alt. B	Alt. C	Alt. ENV.
Inhabitants of Lake Idro	+2334	+2551	+3001	+4493
Farmers	−2817	−12621	−22739	−22739
Agricultural input industries	−2956	−13241	−23858	−23858
ENEL	−1190	−1476	−1675	−1675
Private hydroelectric power producers	−974	−1209	−1371	−1371
TOTAL	−5603	−25996	−46642	−45150

Table 2 ***Maximum thesis.***

	Alt. A	Alt. B	Alt. C	Alt. ENV.
Inhabitants of Lake Idro	+2334	+2551	+3001	+4493
Farmers	−5395	−24165	−43541	−43541
Agricultural input industries	−5660	−25354	−45683	−45683
ENEL	−1190	−1476	−1675	−1675
Private hydroelectric power producers	−974	−1209	−1371	−1371
TOTAL	−10885	−49653	−89269	−87777

Environmental impact assessment

The analysis described in the previous chapter is based exclusively on economic factors, and does not consider other aspects involved in the decision process, such as employment opportunities and environment. A global vision of the problem, which cannot overlook these aspects, requires the decision maker to use more fairness toward all the interest groups involved.
The Environmental Impact Assessment (EIA), as it is known, has been developed as a tool for supporting the public manager in the decision process, even when he has to deal with qualitative variables such as the environmental ones (water quality, landscape, wildlife, flora etc.). In the EIA studies, different methodologies can be used; in this study we chose to apply some procedures deriving from the VISPA (the acronym, in Italian, of Interactive Assessment for Choosing among Alternative Projects) program, developed by A. Colorni e E. Laniado. The program, developed as a decision support system dealing with environmental problems, appears to be reliable for the evaluation of the case here considered The method allows for the participation of the involved interest groups, who can express their point of view through surveys; this requires the decision process to be formal and consequently more transparent and objective.
In this case privileged observers of different interest groups (farmers, people interested working in the tourism industry, environmentalists, etc.)were interviewed. On the basis of the data we had already gained, and the elements we collected in the interviews different alternatives where selected to show the most significant scenarios for the area examined.
For each of the alternatives, eleven indicators were defined. Firstly, we included the indicators that allow quantification of the economic outcome for the main activities mentioned in the previous paragraph. For the social aspects, employment levels were considered while for environmental aspects, qualitative indexes for flora, wildlife and landscape were followed. In this last case, a scoring system derived from the methods described in the scientific literature was implemented. Scores on a one to ten scale were attributed to three indicators describing the impacts (negative and positive) deriving from the different alternatives.
An impact matrix was obtained crossing the eleven indicators with the five alternatives; it represents the basis for later elaboration allowing for the identification of the best alternatives. As already mentioned in the evaluation process two thesis were considered (a minimum and a maximum) that differ in respect to the size of the river basin area that benefits from the waters of the Chiese River.
Tables 3 and **4** show a difference in the scale of measurements that does not allow for a comparison of the different alternatives. To define a hierarchy for the alternatives it is necessary to change the indicators' values into adimensional values. Following the procedure of the VISPA program, utility functions were identified for each of the indicators so that the values, previously expressed with different value measures could be homogenised. A uniform measurement scale representative of the satisfaction level of the community was thus obtained.
Some of the indicators (tourism sales, value added in agriculture, sales of agricultural input industries, and energy production by ENEL and private power plants) can all be considered as values of production of goods and services by the national community as a whole. Three indicators (employment in the tourism industry, in agriculture, and in the agricultural input industry) are expressed in the same scale: the number of employment positions gained or lost. The effects of the different alternatives on flora, wildlife, and landscape are already homogeneous since they are expressed as numeric indexes. The conversion into values expressed as a uniform (adimensional) unit of measurement allows for the estimation of the satisfaction level of the indicator (value-added, employment and natural environment) deriving from each of the alternatives. By convention, the numbers will range between 0 and 1. 1 indicates maximum satisfaction, 0 minimum satisfaction for the community involved with the behaviour of each indicator. We have, in this manner, constructed **tables 5** and **6**.
The economic, employment and environmental indicators were successively aggregated in a single vector for each of the categories involved by the alternative

([1]) This is not a full list of subjects that may be interested in the use of the Chiese River water. There are also, for instance, the riverside dwellers and the fisherman that often complain about the shortage of water during the low water periods.

projects. In the aggregation procedure, a linear operator was used, with coefficients proportional to the relative importance level of each indicator belonging to the same category. We have chosen to consider the employment slightly more important than the economic factor, given the great social variability characterizing the area; we have thus attributed to the indicators of employment levels a 0.6 coefficient, and to the economic indicators a 0.4 coefficient. We assigned a 0.65 and a 0.35 coefficient to the ENEL vector and to the private energy producers, considered as a single factor (named «energy»). Following the input of privileged observers we considered it appropriate to assign a 0.2 to the flora, a 0.4 to the wildlife, and a 0.4 to the landscape indicators. We have consequently built an aggregation matrix, where rows show «indicators/objectives» for each category of activities: tourism, agriculture, agricultural input industries, electric power production and environment; columns show the different alternatives that were evaluated (see **tables 7** and **8**).

The program allows, at this point, for the cancellation of undesirable, or dominated alternatives, following the Pareto's efficiency criterium. In order to make a choice, we consequently had to sort the different alternatives. A possible sorting criteria is based on the summing up of the values calculated for each alternative: the alternative that shows the highest score is considered the best performing one. It was necessary, in order to correctly compare the alternatives, to consider the different weight of the objectives characterising each category of activity and interest group involved. This was possible, on the basis of the response to the surveys we conducted.

After a specific «weight» has been attributed to each of the indicators — which represents the satisfaction level of each category — we had to calculate the weighted sums for each alternative, in order to, at least partially, sort out the alternatives.

We chose to evaluate the opinions of the most relevant interest groups separately — the farmers and the tourism industry — so that the procedure would be more transparent. Finally, we have considered the general point of view of the community as a whole, which is a measure of importance that a public administrator could attribute to the different objectives and to the different interest groups involved.

Each point of view was evaluated through an appropriate preference scale, that for analytical purpose is expressed by a vector with elements (weights) ranging from 0 to 1 (zero if the variable has no use to the interest group, one if it has maximum usefulness). The weight vectors are shown in **table 9** for the Minimum Thesis.

It appears that if the criteria of the weighted sum is used, different results can be obtained depending on the weight attributed to some of the objectives/indicators. In other words, it is not possible to univocal

Table 3 ***Impact Matrix (Minimum thesis).***

	Alt. 0	Alt. A	Alt. B	Alt. C	Alt. ENV.
1) Sales in tourism industry	0	2334	2551	3001	4493
2) Employment in tourism ind.	0	88	96	112	72
3) Agricultural value added	0	−2817	−12621	−22739	−22739
4) Agricultural employment	0	−46	−206	−372	−372
5) Sales in agr. input industr.	0	−2956	−13241	−23858	−23858
6) Employment in agr. input ind.	0	−25	−110	−199	−199
7) ENEL	0	−1190	−1476	−1675	−1675
8) Private hydroel. power produc.	0	−974	−1209	−1371	−1371
9) Flora	0	1	2	4	5
10) Wildlife	0	2	4	5	6
11) Landscape	0	2	4	5	5

Table 4 ***Impact Matrix (Maximum thesis).***

	Alt. 0	Alt. A	Alt. B	Alt. C	Alt. ENV.
1) Sales in tourism industry	0	2334	2551	3001	4493
2) Employment in tourism ind.	0	88	96	112	72
3) Agricultural value added	0	−5395	−24165	−43541	−43541
4) Agricultural employment	0	−88	−395	−712	−712
5) Sales in agr. input industr.	0	−5660	−25354	−45683	−45683
6) Employment in agr. input ind.	0	−47	−211	−381	−381
7) ENEL	0	−1190	−1476	−1675	−1675
8) Private hydroel. power produc.	0	−974	−1209	−1371	−1371
9) Flora	0	1	2	4	5
10) Wildlife	0	2	4	5	6
11) Landscape	0	2	4	5	5

Note: The sales, value-added and power production indicators are expressed in millions of lire, the employment indicators are expressed in number of employees.

Table 5 ***Impact Matrix with adimensional units (Minimum thesis).***

	Alt. 0	Alt. A	Alt. B	Alt. C	Alt. ENV.
1) Sales in tourism industry	0,500	0,549	0,553	0,563	0,594
2) Employment in tourism ind.	0,500	0,618	0,626	0,647	0,596
3) Agricultural value added	0,500	0,441	0,237	0,026	0,026
4) Agricultural employment	0,500	0,438	0,229	0,011	0,011
5) Sales in agr. input industr.	0,500	0,438	0,224	0,003	0,003
6) Employm. in agr. input ind.	0,500	0,467	0,355	0,238	0,238
7) ENEL	0,500	0,475	0,469	0,465	0,465
8) Private hydroel. power produc.	0,500	0,480	0,475	0,471	0,471
9) Flora	0,000	0,100	0,200	0,400	0,500
10) Wildlife	0,000	0,200	0,400	0,500	0,600
11) Landscape	0,000	0,200	0,400	0,500	0,600

Table 6 ***Impact Matrix with adimensional units (Maximum thesis).***

	Alt. 0	Alt. A	Alt. B	Alt. C	Alt. ENV.
1) Sales in tourism industry	0,500	0,525	0,528	0,533	0,549
2) Employment in tourism ind.	0,500	0,544	0,548	0,556	0,536
3) Agricultural value added	0,500	0,441	0,237	0,027	0,027
4) Agricultural employment	0,500	0,456	0,303	0,144	0,144
5) Sales in agr. input industr.	0,500	0,438	0,224	0,003	0,003
6) Employment in agr. input ind.	0,500	0,476	0,394	0,310	0,310
7) ENEL	0,500	0,487	0,484	0,482	0,482
8) Private hydroel. power produc.	0,500	0,489	0,487	0,485	0,485
9) Flora	0,000	0,100	0,200	0,400	0,500
10) Wildlife	0,000	0,200	0,400	0,500	0,600
11) Landscape	0,000	0,200	0,400	0,500	0,600

Table 7 ***Aggregation Matrix (Minimum thesis).***

	Alt. 0	Alt. A	Alt. B	Alt. C	Alt. ENV.
Tourism	0,500	0,589	0,597	0,613	0,594
Agriculture	0,500	0,440	0,232	0,017	0,017
Agr. input industries	0,500	0,456	0,303	0,144	0,144
Hydroel. power producers	0,550	0,524	0,518	0,514	0,514
Environment	0,000	0,180	0,360	0,480	0,580

Table 8 ***Aggregation Matrix (Maximum thesis).***

	Alt. 0	Alt. A	Alt. B	Alt. C	Alt. ENV.
Tourism	0,500	0,537	0,540	0,547	0,541
Agriculture	0,500	0,450	0,276	0,097	0,097
Agr. input industries	0,500	0,461	0,326	0,187	0,187
Hydroel. power producers	0,550	0,537	0,533	0,531	0,531
Environment	0,000	0,180	0,360	0,480	0,580

Table 9 ***Vectors of weight.***

	View point		
	Tourism industry	Farmers	Community
Tourism	0,40	0,15	0,30
Agriculture	0,15	0,40	0,30
Agr. input industries	0,10	0,25	0,10
Hydroel. power producers	0,10	0,10	0,10
Environment	0,25	0,10	0,20

Table 10 ***Alternatives ranking (Minimum thesis).***

Hierarchy	View point		
	Tourism industry	Farmers	Community
1	Alt. ENV.	Alt. 0	Alt. A
2	Alt. B	Alt. A	Alt. 0
3	Alt. A	Alt. B	Alt. B
4	Alt. C	Alt. ENV.	Alt. ENV.
5	Alt. 0	Alt. C	Alt. C

Table 11 ***Vectors of weights from the community viewpoint.***

	Minimum thesis	Maximum thesis
Tourism	0,30	0,20
Agriculture	0,30	0,35
Agr. input industries	0,10	0,25
Hydroel. power producers	0,10	0,10
Environment	0,20	0,10

Table 12 ***Alternatives ranking (Maximum Thesis).***

Hierarchy	View point		
	Tourism industry	Farmers	Community
1	Alt. ENV.	Alt. 0	Alt. 0
2	Alt. B	Alt. A	Alt. A
3	Alt. A	Alt. B	Alt. B
4	Alt. C	Alt. ENV.	Alt. ENV.
5	Alt. 0	Alt. C	Alt. C

identify the best alternative. The large number of indicators/objectives, often conflicting, makes it difficult to consider a single solution. Nevertheless, the evaluation that we conducted is helpful for the decision-maker, since it offers a broad overview of the possible solutions from different points of view.

The analysis of the results brings about some interesting indications: if a «partial» point of view is considered (that of the tourism industry, or that of the farmer) the preferred alternative coincides with the category's main objective. For the tourism industry, the preferred alternative is the ALT ENVIRONMENT that proposes the cancellation of any artificial water excursion in Lake Idro, while for the farmers the best alternative is maintaining the current situation. The hierarchy of the alternatives does not leave much room for mediation, since the importance attributed to the different objectives is biased in favour of everyone's own category.

On the other hand, considering a neutral point of view deriving from a mediation between conflicting interests — which is after all the role of the public administrator looking to the welfare of the community as a whole — ALT. A becomes the best alternative. This is true if the Minimum Thesis is adopted.

If however we consider the effect of the Chiese River extended to the larger area of 59971 hectares, (and therefore the Maximum Thesis is accepted), it is obvious that the public decision-maker will have to place stronger emphasis upon agriculture and the agricultural input industries, in view of the great amount of money involved (about 90 billions lire per year).

Maintaining the weight vectors of **table 9** for the tourism industry and for farmers, we thought it necessary to change the weight vector for the community as shown in **table 11**. In **table 12** the alternatives for the Maximum Thesis are hierarchically organised based upon the new weight vector chosen for the community. If the Maximum Thesis is accepted, the best alternative for the community as a whole is the current situation (water level excursion of 7.0 m). It is obviously the role of the public administrator to make the best choice between the proposed, well-reasoned and balanced alternatives, based on the importance of the different sectors and the different objectives at a regional and national level.

The public administrator has the opportunity to make a rational and well-balanced choice, thanks to the environmental impact assessment procedure. However, the public manager should always remember that its choice should be accompanied and supported by appropriate actions to compensate the losses that could occur to at least part of the community. Such actions could be, for instance, public subsidies to reorganise the irrigation and spring network, or the improvement of the road system in lake shore communities. ●