A valuation of positive environmental externalities in areas subjected to hydrological risk

Angelo Quarto

JEL: Q50, Q15

Keywords: environmental externalities, incentives, agricultural income.

The aim of this paper is to economically evaluate the positive environment externalities produced by agriculture in areas subjected to hydrological risks.
The economical evaluation of agricultural externalities has been the start of the creation of a system of incentives aimed at the reintroduction of ecologically sustainable and profitable agricultural activities in abandoned areas.
In these areas the abandonment of agricultural activities and as a consequence the abatement of maintenance has witnessed an increase in fires and hydro geological instability and in the public resources destined to their control.
The introduction of remunerative agricultural activities, especially in state-owned areas could stimulate new economical activities (e.g. tourism, selling or transformation of regional products) giving new opportunities to young people who have left marginal areas.
Using mathematical programming models it was possible to attribute an economical value to positive environmental externalities deriving from the introduction of agricultural activities in "sensitive" areas.
The study was conducted on the hills of the National Park of Cilento and Vallo di Diano.

1. Development opportunities linked to territorial valorization.

In developed countries the poorness of natural resources is caused from a growth model made of a high demand of good and services without respect for the needs of environmental protection and of life quality. At the same time, in these countries, is not again possible stop the destroy and start an overturn of the trend, targeting the development of production and the services to the environmental protection. Along this interpretation there's the start for the sustainable development meaning able to integrate the needs of economic and social growth with the protection of environmental resources in the respect of next generations.
A sustainable development able to give further advantages such as the possibility to protect the integrity of natural resources reducing the risks of hydrogeological expiration, flood, burning and so, risks for population in risks areas. At the same time it contributes to prevent some damages in terms of natural catastrophes performing the protection, reducing public expenditure. The protection of environmental resources realizes not only goals of inter generation equity, but realizes a strong effect in terms of economic activities that, just from environmental and territorial protection, have occasions of development. Protection and valorization of environmental resources are linked as a virtuous cycle able to promote the dissemination of new economic activities and new employment.

2. Agriculture in sustainable development.

Agriculture is a filed in which the soil is linked with the environmental resources. Its quantitative and qualitative help has expressed not only in terms of not renewable resources directly used in the production process but also in terms of new structuration of natural environment.
In other economic fields, such as industrial field, production processes are integrated with environment in negative terms, trough the exploitation of natural resources and the output of pollutant agents.
According to its organization and to production techniques, agriculture could generate negative or positive external effects on the natural surrounding environment: the first ones (negative externalities) are caused from an excessive and not rational exploitation of natural resources having negative effects on environment and citizenship; the second ones (positive externalities), are linked to the protection and valorization of environment and involve, the control of territory, the protection of landscape from an esthetical point of view and in terms of biodiversity protection. The role of equilibrium from agriculture under the environmental profile opens to a compatibility between the growth of production and environmental protection that is not possible in other fields.
Consequently, a real sustainable development depends from the capability to adopt in the agricultural field agri – environmental politics that are efficient, able to stimulate participation of companies and local human resources and a program of development coherent with environmental goals, secondly form the introduction of vincula and restraints of pollution in the economic fields that have an only negative influences on environment.
If sustainable or eco compatible agriculture dissemination is limited in advanced countries, the need to conjugate in a very efficient way agricultural production and environmental protection, is highly important either in undeveloped countries than in rural and marginal areas of some advanced countries in which the territorial reality is far from homogeneity. Agriculture, often, represents the only source for survival and revenue, contributing to avoid mass emigration to cities, abandon of territory, main causes of some phenomena of desertification, hydrogeological damage and degrade of environmental and social and economical environment.
So, in marginal areas, agricultural production and protection of natural environmental vocation, will be possible to stop the rural poorness, stop the urbanization process, stimulate growth and improve, finally, the quality of life.
The last politics adopted to pursue a sustainable development have been not so efficient: this paradigm seems just far from an actuation- in this context, agriculture will have a strategic role. In fact, it’s possible to recognize that agriculture produced positive externalities and that is the attribution to the field of a capability to go through the dichotomy between environment and economic growth, opening to a development will be really compatible.

3. Environmental externalities of agriculture.

In the economic system, agricultural production interacts with environment in positive and negative. In fact it’s source of negative environmental externalities, caused from an exploitation of natural resources that have a negative effect on the wellness function of other subjects, generating costs that the farmer does not pay. On the other hand, it's source of positive environmental externalities, because it contributes to the valorization of environment giving, without an economic return, some environmental services: management and safety, protection of landscaping esthetical quality and maintaining biodiversity. These services have a positive effect on the economic wellness function of subjects that are far from this activity, that, although prefer these services, have not costs because the services are public.

Environmental goods and services, for their public nature have not a market in which there is a price because there is the absence of conflict in consume and the excludability from benefits, absence for which commercialization is impossible.

In a conventional market it allows farmers to have a privileged position towards natural resources, because, a use price comprehending environmental damages (negative environmental externalities) doesn't exist, they make an exploited use not caring of the costs for society.

At the same time, farmers don't receive remuneration for the environmental services that they give (positive environmental externalities), because from them is not possible to exclude someone, and if it could possible, it's too expensive.

From this we have a "free-rider" behavior because each one, even if gives a very high value to a service or an environmental (public) good, under estimates or does not express a positive preference toward this service (good), because is aware that he follows to use within there are other subjects able to pay. Environmental goods and services are considered collective consumptions for which is possible the use without participate, adequately to their financing. In this way, the farmers that organizes the production with specifically techniques and generate negative externalities (worsening the function of wellness for others) continue to make their activities without caring, meanwhile the farmers for which the activity is source of positive externalities (improving the functions of wellness for others) are not stimulated to continue the activity.

Farmers that polluted environment do not pay for the damages and at the same time don't receive any remuneration for environmental services, the net balance among negative and positive externalities, if there is not an intervention in the direction of a monetary quantification that allows to internalize in the economic private calculation the social costs and to remunerate the environmental services, will record a prevalence of negative externalities with a dangerous prejudice for environment either in the supporting function for agricultural activity than in the function of supply of direct utilities.

What we want to underline is the influence that agricultural activity has on the economic wellness. It influences the function of individual utility either directly than indirectly, giving agricultural products of the satisfaction of main needs and indirectly through the not intentional manifestation of positive and negative externalities that don't be considered. Agricultural activity has recognized for its double function: production of agri – food goods (productive function), production of externalities (environmental function).

4. Tools of agri – evironmental politics

Economic theory concerned of negative externalities: pollution and damage of natural resources stocks.
That one because the impact of economic activity on environment has been negative making an environmental degrade with a following worsening of quality life (wellness). Environmental degrade has been more and more evident and critical and policy makers deal with the formulation of economic politics of protection goals and environmental valorization, then to control the negative externalities and to promote the positive externalities trough a supporting to the expansion of not ,marketing activities (such as environmental function of agriculture). In past time, agriculture, rarely represented an impact factor on environment. In fact farmer used, natural and handcraft tools that modified environment only a bit, giving an explicated function of defense of environmental resources and of environmental quality. Since Second World War the relationship between agriculture and environment has turned becoming with a positive sign. That means that agriculture, when has been exeercited in a sustainable way should be able to make a very important environmental function and, this time, not in an implicit way.
A big part of economic literature think that economic interpretation of environmental impacts, that is the monetary evaluation of environment, is important to comprehend the reasons of the phenomenon and to individuate the more adequate care politics (Baumol, Oates 1988).
We have already said that environmental impacts (externalities) have origin because the economic system, that are the production and consumption activities and the exchange relations of goods among subjects, is not able to record in an economic way these interactions (environmental positive and negative externalities).

5. Cross- compliance subsidies and agri-environmental development

The purpose of this paper is to set up a monetary quantification of the environmental services through a rigorous procedure which can legitimate the definition of specific environmental subsidies to farmers. The attention has been focused on the environmental service originating from the “soil erosion saving” which follows the reintroduction of appropriate crops and practices in the inland marginal areas.
From the farmer’s point of view the expected revenue comes from two different sources: the first comes from the selling of commodities on the market, the second from the subsidy for the decrease of the soil erosion that the crop’s reintroduction could cause to the environmental maintenance. The latter revenue should represent the cross-compliance subsidy to repay the agricultural net externalities.
In order to obtain a correct evaluation of such an environmental service, which would have to change farmer’s choices, a series of microeconomic models has been developed to simulate reliable farmer’s behaviors.
Such an analysis gains more sense and feasibility when referred, as it is the case of the following model, to the State-owned marginal lands.

The appraisal of the environmental net positive externalities aims to estimate the value of the cross-compliance subsidy to be given to farmers in the marginal areas exposed to soil erosion risks.

5.1 The methodology for estimating "soil erosion saving"

The positive net externalities appraisal refers to an integrated approach by using several operative instruments. The whole appraisal methodology is organized along three phases as follows:
1. delimitation of high risk areas from the soil erosion point of view;
2. identification of agricultural activities, which are compatible with the environmental protection needs;
3. appraisal of the net positive externalities that can be generated by the reintroduction of appropriate agricultural activities in the marginal lands.

Once the optimal crop pattern for a specific land and have been selected, an environmental indicator has been identified to measure the level of the land protection that can be guaranteed by the different crops.

5.2 Environmental service appraisal

Both the selection of the "typical" agriculture and of the environmental indicator represent the informative basis on which four logically-linked linear planning models has been elaborated to estimate the reduction of the total erosion.
The 3rd phase is then referred to the evaluation of the cross-compliance subsidy to be granted to those farmers aiming to introduce erosion-saving activities in marginal selected lands.
From a methodological point of view the highest difficulty consists in the appraisal of the net positive externalities and in the search for compatibility conditions.
In order to estimate the environmental service deriving from the "soil erosion saving" (SES), several crop practices with different erosion impact has been developed for each farm. A maximum farm's extension of 10 hectares has been considered and a series of representative processes of agricultural destinations have been defined by applying linear programming models. Finally, a multiple objective programming technique (Compromise Programming) has been used to identify the optimal combination between erosion and gross income.

Model 1: EROS (erosion minimization)
The first model aims to minimize the total erosion, given the actual crop and agronomic techniques.
The model uses technical data such as: specific erosion for each farming, hours of work, different availability of labor all year round, production yields, etc.
Analytically the model comes in the following form:

$$\text{Min } Eros = \Sigma_j X_j Ce_j$$

subject to:

$$\Sigma_j \ (a_{ij} \ X_j) \leq b_i$$

$$X_{ij} \geq 0$$

where:

– j is index of the j^{th} activity
– i is index of the j^{th} resource
– Eros is the objective function and indicates the total erosion to be minimized, measured in tons.
– X_j indicates the j^{th} activity
– Ce_j indicates the j^{th} activity's erosion coefficient units (tons per ha)
– a_{ij} indicates i^{th} available resource use technical coefficient by the j^{th} productive process
– b_i indicates the available amount of the i^{th} resource (i.e the i^{th} land class).

The model present an odd solution where the optimal farm plan excludes any crop activities as they generates soil erosion. The optimal solution presents a zero erosion level and 0 gross income (Eros 1).

Then a second version (Eros 2) has been developed in order to take into account a more realistic situation where all arable land is used according to the actual crop distribution (with minimum constraint).

Tab. 1
Solution obtained from the models Eros1 and Eros2

Description	Production mix (hectares)	Erosion (ton)
Model Eros 1 without minimum constraint	0	0
Model Eros 2 with minimum constraint	1 hectare Ol A; 9 hectares Wh A	36

- Ol A = olive tree with cover 70%
- Wh A= wheat

The synthetic indicator of soil erosion, has been built on the base of studies on the hill of southern Italy (Basso F., 1995), has been calculated for removed soil, for hectare in every year and for every type of crop.

Abbreviation	Tecnique	Coefficient of soil erosion (t/hectare)
Wh A	Wheat “trasversale”	1,79
Wh B	Wheat “rittochino”	2,24
oli A	olive tree with cover 70%	20
oli B	olive tree with cover 37%	40
oli C	olive tree with cover 10%	60

The wheat “trasversale” has a lower part level of soil erosion and a lower level of productivity than the wheat “rittochino”.

Model 2: Gross income maximization (max GI) in the presence of environmental constraint
The second model assumes that the farmer maximizes gross income under the traditional constraints and a further constraint given by a fixed erosion threshold. This level is derived from model Eros 2.
The second model can be formalized as follows:

$$\text{Max GI} = \Sigma j\ PjXj - Cj\ Xj$$

subject to:

$\Sigma_j\ (a_{ij}\ Xj) \leq b_i$ traditional constraints

$\Sigma_j X_j Ce_j \leq e^*$ environmental constraints

$X_{ij} \geq 0$

where
– j is index related to the activities
– i is index related to used resources
– RL is the objective function and indicates the gross income to be maximized
– Xj indicates the jth activity
– Pj indicates an income coefficient of the jth activity
– Cj indicates the unitary production cost for the jth activity
– e* indicates the optimal erosion quantity that must not be exceeded
– Cej indicates the jth activity’s erosion coefficient
– aij indicates the ith available resource use technical coefficient by the jth productive process
– bi indicates the available amount of the ith resource.
– e* is fixed exogenously and, for a specific value, corresponds to the solution of model 1.

This model maximizes farmer’s gross income using the same constraints as in model 1 (Eros 2), but with the additional restriction that the selected productive mix should not cause a global erosion greater than 36 ton.
The model 2 computes the optimal land allocation in terms both the economic and the environmental constraints. The farmer could be considered as a target to be achieved.
The gross income is € 5.472,38.

By using the marginal value of the environmental constraint (dual model), the shadow price for the erosion can be evaluated.
The shadow price of the environmental constraint provides a monetary estimate of the environmental impact generated by the farmer.
The shadow price is equal to € 39 per ton of soil eroded. (Tab. 2).

Tab.2
Solution obtained by Model 2

Description	**Production mix (hectares)**	**Erosion Treshold (ton)**	**Erosion Shadow Price (€/ton)**	**Gross Income Maximized (€)**
Model 2	0,76 Oli A; 9,24 Fru	36	39	5.472,38

Model 3: Gross income maximization in absence of environmental constraint

In the absence of any environmental constraints, farmers would maximize gross income by only taking into account the sets of the technical constraints. The solution obtained simulates actual farmer's without any environmental constraints; that is what actually happens in real life.
The optimal solution will cause an erosion of 75.4 ton and a gross income equal to € 7,020.20 euro (702.02 euro/hectare).

Tab.3
Solution obtained by Model 3

Description	**Production mix (hectares)**	**Erosion (t)**	**Gross Income Maximized (€)**
Model 3	3 ha Ol A, 7 ha Wh B	75,4	7.020,20

Computation of the subsidy in the hypothesis of a threshold erosion level.
In order to obtain a first estimate of the subsidy (i.e. the net positive externality) to be granted to the farmer, the "soil erosion saving" (SES) is computed as difference between the erosion caused by the optimal plan of model 3 and the erosion threshold (i.e. 75.4 – 36 ton, divided by 10 hectare, times 3.9 euro).
The net positive externality generated by the introduction of sustainable agriculture is estimated in 153.66 euro per hectare which represents the subsidy to be granted to the farmer for the service to the erosion saving.
Nevertheless such a solution could be socially inconsistent as the erosion threshold could not be socially accepted. Therefore, a further analysis has to be accomplished to obtain more suitable solutions.
Identifying the optimal mix between income maximization and the soil erosion saving In order to obtain the efficiency frontier (the Pareto optimal set of solutions) the Model 2 has been solved parametrically for different degrees of soil erosion.

Tab.4
Solution obtained by Model 2 solved parametrically for different degrees of soil erosion.

Point	Erosion	Gross Income (€)	Shadow price (€)	Ol A (hectare)	Ol B (hectare)	Ol C (hectare)	Wh A (hectare)	Wh B (hectare)	Total (hectare)
A	5	1,103	217.50					2.23	2.23
B	10	2,206	217.50					4.46	4.46
C	15	3,309	217.50					6.70	6.70
D	20	4,413	217.50					8.93	8.93
E	25	5,044	39.00	0.15				9.85	10.00
F	30	5,239	39.00	0.43				9.57	10.00
G*	36	5,473	39.00	0.77				9.23	10.00
H	40	5,629	39.00	1.00				9.00	10.00
I	45	5,824	39.00	1.27				8.73	10.00
L	50	6,019	39.00	1.55				8.45	10.00
M	60	6,409	39.00	2.12				7.88	10.00
N	70	6,799	39.00	0.13				7.52	10.00
O**	75	7,020	x	3.00				7.00	10.00

* Model 2 Solution
** Model 3 Solution

In accordance with Zeleny's choice policy axiom, the optimal point is the most efficient solution closest to the ideal point under an environmental and economic profiles.

The coordinates of such an ideal point are derived from the optimal values of the two objectives in conflict: the minimal erosion (derived from the minimization of erosion in ideal situation: 18 ton) and the maximum gross income (derived from maximization of gross income: 7,020.20 euro)

The distance from ideal point is calculated by using the following formula:

$$dj = \left[\left| \frac{Z_j^* - Z_j(x)}{Z_j^* - Z_{*j}} \right| \right]$$

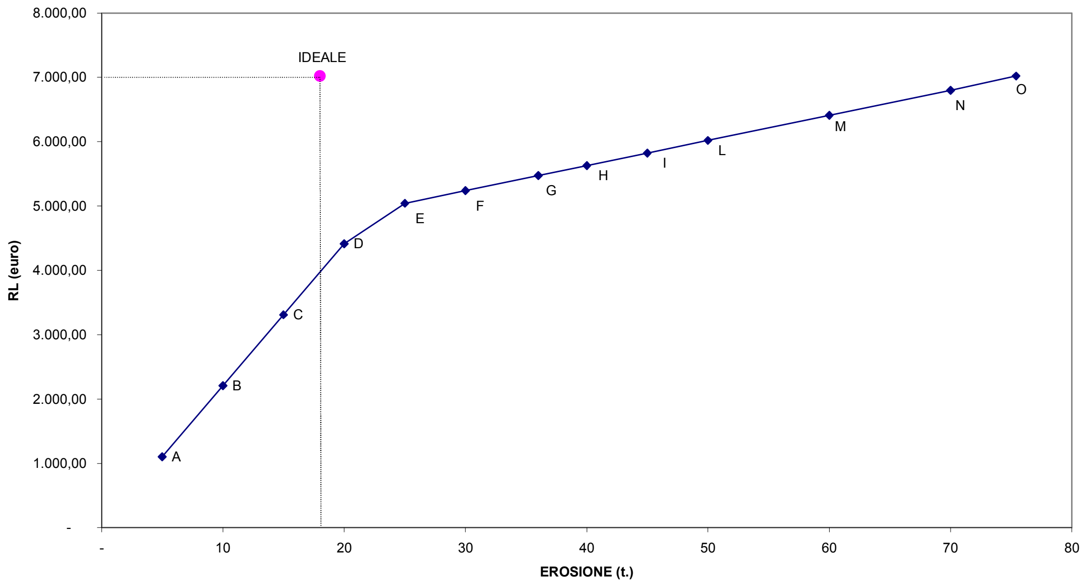
Where:
Z_j^* is the ideal point
$Z_j(x)$ is the j[th] efficient point
Z_{*j} is the anti-ideal point

Then the optimal point is E, corresponding to an erosion level of a 25 tons and a gross income of 5,044 euro (€ 504.4/hectare).

Tab.5
Table of distance from ideal point

Point	Distance
A	0,535
B	0,565
C	0,348
D	0,342
E	**0,335**
F	0,460
G	0,610
H	0,710
I	0,835
L	0,960
M	1,210
N	1,460
O	1,594

Fig. 1
Efficiency frontier



In the case-study, a movement from a gross income maximum in absence of environmental constraint to another, which maintains a more suitable erosion threshold, will produce a SES estimated in 50.4 tons (75.4 – 25) which, multiplied by the shadow price of 39 euro per ton of erosion, correspond to a total amount of 1,965. euro (196,5 euro per hectare).
A tax aimed to punish high environmental impact behaviors might be applied to induce farmers to adopt solutions that imply an introduced to pay for environment oriented behaviors. In both cases the value is equal to the marginal price of the erosion multiplied by the quantity of erosion caused (tax) or avoided (subsidy).

As the aim is to design conditions to attract new farms that will adopt environmentally appropriate practices, the Government should choose to give subsidy to a farmer than to apply a tax.
In order to attract a new farm in the selected marginal area a cross-compliance subsidy of 196,5 euro per hectare, should be granted to farmers only to repay for the net positive externalities. Futhermore it could be interesting to stress that such amount is much lower than the average Government expenditure per hectare used for the environmental protection (about 1.300 euro per hectare).

6. Conclusions

Agriculture can play an important role for the land protection by maintaining a compatible productive function. The target of profit is guaranteed, provided that farm dimension and cross-compliance subsidy insure an effective attracting function.
Assuming that in the marginal areas the economic revenue is insufficient to attract new farms, a subsidy should be given to farmers weather they provide production of environmental services. The subsidy could be estimated by evaluating the physical contribution to the soil erosion saving, which could be derived from the introduction of suitable crops.
If the global revenue reaches a significant value per hectare, agriculture will play an effective environmental role in the field of land protection.
Farmers will be able to play a role of public interest, aiming to receive a subsidy that equals the net positive externalities they generate.
Many benefits of such a solution can be described as follows :
– the Government might achieve the target of environmental protection, by stimulating the farmer's behavior through cross-compliance subsidy, and probably will also reduce the maintenance costs;
– The cross-compliance subsidy would be socially fair because it would pay for the production of public goods;
The backward region would gain in terms of new farm growth and new occupation.

References

ALLIANCE ENVIRONNEMENT (2007) Evaluation Of The Application Of Cross Compliance As Foreseen Under Regulation 1782/2003 Part II: Replies To Evaluation Questions Final. A report for DG Agriculture.

BALDOCK D. *The Concept of Cross Compliance and its Possibile application within the Common Agricultural Policy,* Institute for European Environmental Policy, London, 1993.

BALDOCK D., MITCHELL K. *Cross Compliance within the Common Agricultural Policy,* Institute for European Environmental Policy, London, 1995.

BATIE S*.* Sustainable Development: Challanges to the Profession of Agricultural Economics, *Am. J. Agr. Eco,* dicembre 1989.

BAUMOL, OATES The Theory of Environmental Policy, Cambridge University Press1988.

BRESSO M*.* Teoria economica e ambiente: lo stato della questione, *La Questione Agraria*, n. 41 1991.

BROMLEY D.W *The Environmental Implications of Agriculture,* Staff Paper Series, n. 401,University of Wisconsis – Madison, 1996.

Closs, G., Rhodes, H., Townsend, C., (2007) Stream ecosystem health outcomes of providing information to farmers and adoption of best management practice. Journal of Applied Ecology 44, 1106-1115.

COASE R.H. "The Problem of Social Cost", *Journal of Law and Economics*, n.3, 1960.

DALY, H. E., "Sustainable Growth: An Impossibility Theorem," *Development,*3(4), 1990.

DE JANVRY A. e SADOULET E., Quantitative development policy analysis, The John Hopkins Univ. Press, Londra, 1995.

ERVIN D.E, HEFFERNAN W.D, GREEN G.P. "Cross Compliance for Erosion Control", *American Journal of Agricultural Economics,* n. 4, 1984.

EUROPEAN COMMISSION (2007) Report form the Commission to the Council on the application of the system of cross-compliance. COM (2007) 147 final.

HARVEY, D.R., *Agri-Environmental Multifunctionality: Further Consideration,* SWARD Conference 'South West Agriculture, Octomber 2002

HAZELL P., NORTON R., "Mathematical Programming for Economic Analysis in Agriculture", Macmillan, 1986.

HODGE I., "Agri-environmental Relationships", *The World Economy*, 23, 2000

LATACZ-LOHMANN, U. *Beyond the Green Box: the economics of agri-environmental policy and free trade*. Agrarwirtschaft 49 (9/10) ,2000

MILLER G. T. *Ambiente, Risorse, Sostenibilità*, Piccin Nuova Libreria, Padova, 1997.

OECD, *Multifunctionality: Towards an Analytical Framework*, Paris 2001.

PEARCE D., MARKANDYA A. Environmental Policy Benefits: Monetary Valuation, OECD 1989 Paris.

PEARCE D., TURNER K**.,** BATEMAN I., Economia ambientale . Il Mulino, Bologna 2003.

VATN A., BROMLEY D.W. "Externalities: a Market Model Failure", *Environmental and Resource Economics*, n. 2, 1996.

ZELENY M., (1982) "Multiple Criteria Decision Making", McGraw Hill.

ZILBERMAN D., MARRA M. Agriculture Externalities, in *Agriculture and Environmental Resource Economics,* edited by Zilberman, Miranowsky 1993.