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A METHODOLOGY TO MANAGE ENVIRONMENTAL EFFECTS OF CROP-SHELTER COVERAGE

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ABSTRACT There is a growing concern about sustainable use of territorial resources at both national and local levels. Enhancement of agricultural production, from one hand, and actions aiming at the prevention of environmental degradation, on the other hand, have to be monitored by using suitable land-use and environmental indicators within causal-chain framework models (e.g. Pressure-State-Response or PSR; Driving force-State-Response or DSR; and Driving force-Pressure-State-Impact-Response or DPSIR). Description and quantification of these indicators provide local authorities with suitable tools to carry out decisions apt to contain the impact on the environment within adequate thresholds by means of standards and regulations. Among intensive agricultural production, crop shelters contribute to the modification of the environment by acting on different factors. In this study some land-use and environmental indicators were defined within a causal chain framework suitable to the environmental management of crop shelters. A methodology based on the characterization of these indicators made it possible to define an index which describes the level of soil occupation over time due to crop shelters and could be used to manage the localization of protected cultivations. The methodology was applied in a highly representative protected cultivation area located in south-eastern Sicily (Italy). The results produce thematic maps of the indicators and index values in the different zones of the study area. Taking into account both the level of crop shelter coverage and its time modification, the index constitutes a basic knowledge for local authorities to deal with problems related to the reduction of the environmental impact.

Keywords: greenhouse, GIS, digital image, image processing.

INTRODUCTION Protected cultivation is a steadily growing agricultural sector worldwide currently reaching over 500,000 ha of plastic-covered greenhouses. A higher growth is registered in east Asia, especially in Japan (70,000 ha), and in the Mediterranean basin, where the plastic greenhouse area exceeds 130,000 ha (Agüera & Liu, 2009). In Europe, at present, extensive greenhouse areas are located in the coastal areas of the Mediterranean, especially in Spain where there is one of the largest concentrations of intensive horticulture under plastic greenhouses in the world with a surface of approximately 25,000 ha. In south-eastern Sicily, the greatest presence of these temporary constructions is registered in coastal areas, mainly as plastic greenhouses or tunnels used for horticultural and floricultural breeding as well as plastic coverings for vineyard pergolas. Along the coastal area of the Province of Ragusa horticultural and floricultural protected cultivations cover an area of more than 7,000 hectars (tunnels and hard-covering structures), representing about the 67% of the total surface of protected cultivations in Sicily and the 17% of the whole national surface that amounts to about 29,000 hectares (ISTAT, 2000).

In territorial areas characterized by intensive agriculture, the environmental effects caused by the spreading of crop shelters can be analyzed using a causal chain framework (e.g. Pressure-State-Response or PSR; Driving force-State-Response or DSR; and Driving force-Pressure-State-Impact-Response or DPSIR), as the economic activity connected to protected cultivation, leading to changes in the state of the territory, could be considered as a driving force that exerts pressure on the environment. In these frameworks the forces acting on the environment, the changes that, as a consequence, take place and the social reaction to these changes are identified and described by suitable indicators (Cloquell-Ballester et al., 2006; Colantonio Venturelli & Galli, 2006). To analyze the environmental effects of crop shelters by means of causal-chain models as well as to adopt methodologies and tools aimed at reducing their negative effects, the knowledge of crop-shelter extension, location, and spread over time is required. This can be achieved by consulting and analysing thematic maps that, if available, are often difficult to update due to the temporary character of crop shelters. In this regard, the technicians responsible for the development of crop-shelter maps can take advantage of pattern recognition methods, as they can reduce significantly the time required for the preparation of such maps (Arcidiacono & Porto, 2007; Agüera & Liu, 2009; Arcidiacono & Porto, 2009b). The knowledge of crop-shelter extension, location, and spread over time is even more important when territorial areas are lacking of specific planning tools and regulations regarding the building of these type of constructions. Because of these legislative gaps and in absence of public controls, the greenhouse growers often act according to their convenience (Agüera & Liu, 2009) and, therefore, their behaviour contributes to environmental degradation.

The present study defines an index that describes the land cover characterized by crop-shelter and its variation over time. By allocating crop-shelter load according to maps of the index value, relevant authorities will be able to reduce crop-shelter environmental impact.

MATERIAL AND METHODS The methodology proposed for calculation of the index (Fig. 1) provides for the definition of a DPSIR model, in which indicators are described and computed in the appropriate spatial and temporal scale (Potschin, 2009). The indicators classified as I_{DPSIR} are subdivided into: I_{DRI} indicators that describe and quantify the driving forces causing crop shelter environmental impact; I_{PRE} indicators that describe and quantify the pressure exerted on the environment by the activities related to the driving forces; I_{STA} indicators that describe and quantify the state of the environment subject to intensive protected cultivation; I_{IMP} indicators that describe and quantify the impacts on the environment; I_{RES} indicators that describe and quantify response actions to be carried out by local authorities needed to mitigate the environmental damage.

On the basis of this information the methodology provided the computation of the index for the current state and for different planning hypotheses (Arcidiacono & Porto, 2009a). This latter condition simulates the changes in crop shelter spread over the territory due to a policy action. The amount of crop-shelter load to be dislocated is defined by the appropriate Local Authority.

The i_{SO} index, which describes, in the current state, the level of soil occupied by crop shelters in the zones considered, is defined as:

$$i_{SO_i} = \frac{I_{CS}}{S_A} \tag{1}$$

where the indicator I_{CS} belongs to the I_{STA} category and describes and quantifies the surface of crop-shelter coverage, and S_A represents the available surface to localize crop-shelter load in the territory. The computation of S_A is carried out by quantifying an indicator I_{AL}, suitable to describe other anthropic loads different from I_{CS}, and some indicators I^*_{DPSIR} defined in the DPSIR model, apt to describe and quantify the areas unsuitable to crop-shelter building. The surface area S_A is, thus, computed following the relation:

$$S_A = S_{TOT} - S_{AL} - \sum_k S_{DPSIR_k} \tag{2}$$

where S_{tot} represents the surface area of the considered zone, and S_{AL} and S_{DPSIR} are the surfaces characterized by the indicators I_{AL} and I^*_{DPSIR}, and k identifies the number of indicators I^*_{DPSIR} which characterize some areas within the considered zones unsuitable to crop-shelter building.

The index i^P_{SO} in the planning hypothesis is computed by following two different criteria that depend on change over time of crop shelter coverage. If there is no temporal variation, or in absence of this type of coverage, then the first criterion applies, i.e. the computation of crop shelter load is based on the available soil surface, in the considered year (eq. 2). If the surface area of crop shelters varies in time then the second criterion applies, i.e. the computation of crop-shelter load is based on both the variation in time of their surface area and the available surface area. Furthermore, the methodology provides the use of a parameter q (Arcidiacono & Porto, 2009a) which allows crop-shelter building also in the zone having the maximum load.

CASE STUDY To clarify the application of the proposed methodology as well as to highlight its feasibility to crop-shelter coverage management, the computation of the index i_{SO} was performed in a case study regarding the territory of the Municipality of S. Croce Camerina (RG), a crop-sheltered area in the Province of Ragusa located in South-eastern Sicily (Italy). In this region a high relevance of crop shelter coverage and a particular lack of specific regulations and planning tools for its management exist. In detail, since literature contains no studies concerning causal chain frameworks of protected cultivation agricultural activity, a DPSIR model was built on the basis of information collected from the Landscape Plan of the Province of Ragusa (County councillor of territory and environment, 2004; Fusero & Simonetti, 2005). The definition of the indicator set was carried out at the province scale and according to the temporal scale of available territorial data.

In order to analyze the spatial distribution of crop shelters, the considered territory was subdivided into 11 zones and the available digital imagery referring to years 1994 and 1999 were used. The indicator I_{CS} was, therefore, quantified by the crop shelter surface areas related to these years, named $S_{CS,1994}$ and $S_{CS,1999}$, respectively. In the absence of available thematic cartography for 1994, a semi-automatic classification of crop shelter coverage needed to compute the surface area $S_{CS,1994}$ was performed, following a previously defined methodology (Arcidiacono & Porto, 2009b). To compute the surface area $S_{CS,1999}$, the existing thematic cartography of crop shelter coverage related to 1999, which is part of the Landscape Plan of the Province of Ragusa, was used. Finally, to compute I_{AL} and I^{*}_{DPSIR} indicators, information contained in the Technical Regional Cartography (TRC), in the Territorial Plan of Coordination and in several thematic maps of the Landscape Plan of the Province of Ragusa related to territorial restrictions, territorial protection levels and land uses were used.

To calculate the index i^{P}_{SO}, the crop-shelter load to be allocated in the territory was fixed, as an exemplification, equal to the crop shelter planimetric surface located in protected areas under the hypothesis that the policy actions made by the appropriate local authorities aim at removing crop-shelter load from these areas.

RESULTS The results of crop-shelter coverage variation in each zone in the period 1994-1999 and the i_{SO} index variation from the current state to the planning hypothesis are shown in Fig. 2. In this study crop-shelter building was supposed not to be allowed in the zone where the crop-shelter load variation over time is maximum (q=1). In the zones where there was no crop-shelter coverage in the considered period (i.e., zones 6, 9-11), as the index i^{P}_{SO} is normalized with reference to S_A, equal values of the index i^{P}_{SO} are obtained (35.8%). In zone 1, where the crop shelter load did not vary in the considered period and the value of the index i_{SO} in the current state was high (about 98%) the planning hypothesis provided a minimum increment of the index i_{SO} of about 0.6%. In general, the zones subject to a higher increase of crop shelter load during the considered period, were given a lower load increment, even though taking into account also their available surface it could confer a higher load increment to zones with more available surface area.

The application of the proposed methodology made it possible to obtain the index map and a set of indicator maps which could constitute thematic layers of territorial plans suitable to produce response actions within causal chain frameworks.

CONCLUSION The use of the proposed index may allow local authorities to carry out decisional processes useful to keep crop shelter environmental impact within suitable thresholds by means of standard, regulation and guideline enforcement.

If local authorities will apply the map of the index to manage and control crop-shelter building activity, the monitoring of crop-shelter load, performed by means of automatic classification approaches, would be crucial to understand how these type of building have

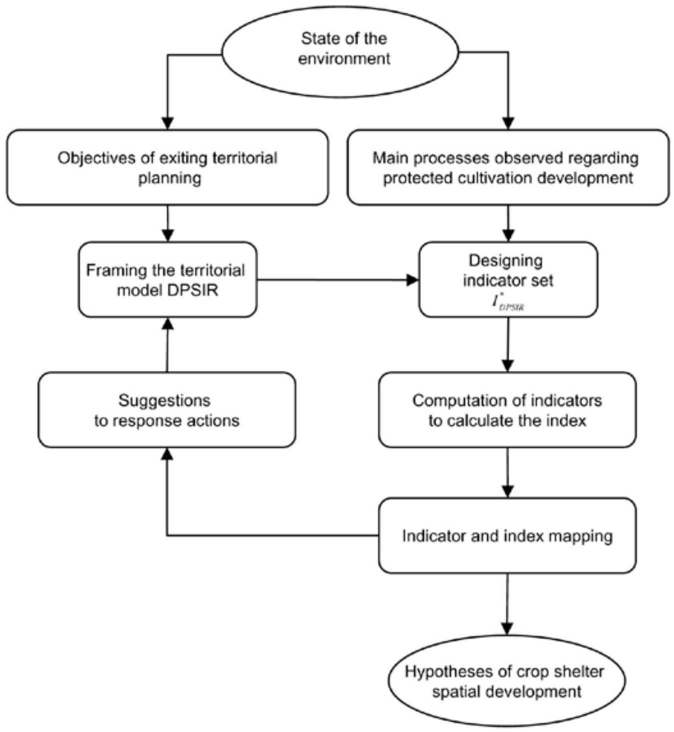

Figure 1. Block diagram of the proposed methodology.

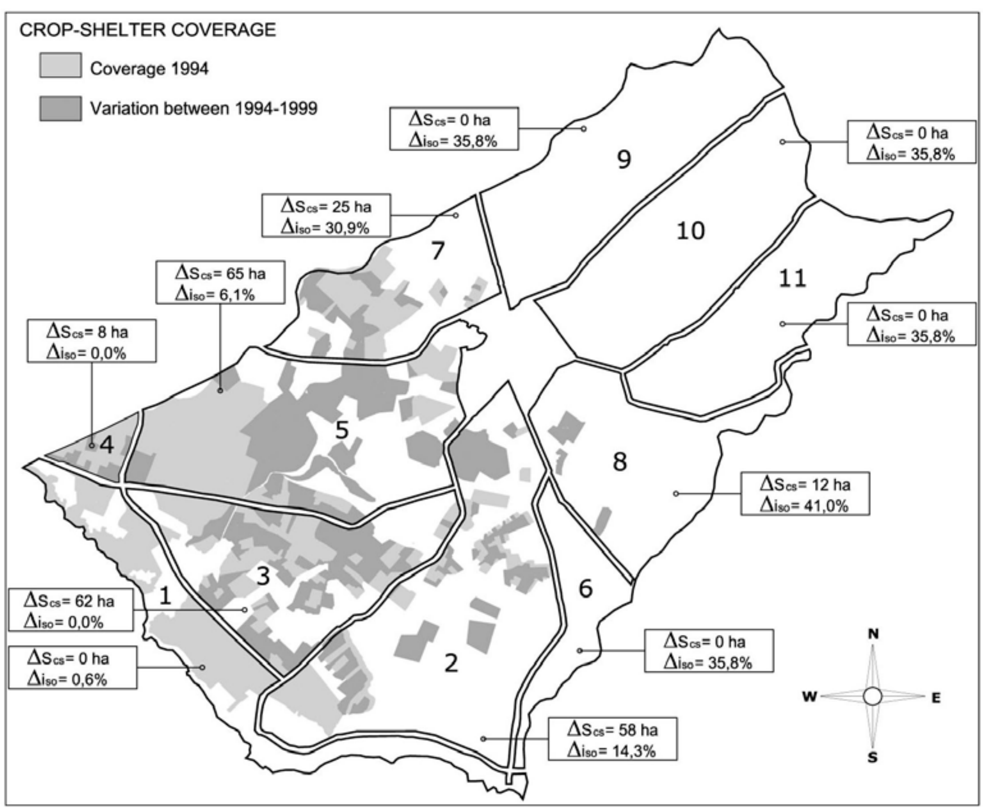

Figure 2. Variation of crop shelter coverage in the period 1994-1999 and variation of i_{SO}

index from current state to planning hypothesis.

been allocating, i.e. aggregation to other existing crop-shelter areas or new settlements.

Further improvements of the methodology results could be the refinement of the classification results by using high resolution multispectral satellite images (e.g. QuickBird and Ikonos), and the quantification of other indicators described in the DPSIR model (e.g. landform indicators, and landscape structure indicators).

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