Consequence of land use changes into energy crops in Campania region

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Abstract

Campania region is undergoing a new and important land use change (LUC). Large areas under tobacco are experiencing a severe economic crisis and cereal areas, especially in the hill, are cultivated with increasing difficulty, with poor economic results (yield value of 2.5 t/ha/year) and under the risk of erosion. No-food crops suitable in these contexts are the perennial and in this case, the land use change would certainly lead to a positive impact on reducing erosion, but also on the reduction of nutrient requirement, on fuel consumption and perhaps it would also lead to an increase in profitability. The aim of this work is to identify the areas in which the land use change could be realistic and ecologically compatible and to evaluate the main consequence of the LUC. The study area includes the entire Campania region. It has been assumed that the areas that will undergo the LUC will be the hilly, not-irrigated cereal crop, with altitudes between 400 and 750 m a.s.l., not included in natural parks, in the Site of Community Importance and in the Special Protection Areas. Through the climate model, inferred from the Ground Water Protection Plan, the area to be examined was classified as 'cold Lauretum', which is a good area for the *Arundo donax* crops up to 750 m a.l.s., with recoverable biomass yield of about 12.6 t/year. The erosion has been estimated with RUSLE applied to the whole region. Using the ESRI ArcGis 10.0 software, seven large areas, partially convertible, were identified. The area that is realistic to convert amounted to approximately 500 km2. The value of the biomass production has been evaluated in the order of 25 million euro a year; actual wheat production would be 33 million euro a year but the production costs are far greater.

With LUC there is a reduction in soil erosion in the order of 300000 t/year. This would lead a saving, on global scale, in the order of 10 million tonnes of CO_2 per year.

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Introduction

We are certain that Campania region, one of the most important agricultural territory in Italy, is undergoing a new and major Land Use Change (LUC). The analyses of LUC are crucial to understanding several environmental phenomena (Lambin *et al.* 2001; Pelorosso *et al.* 2009) but also to develop the prediction of the new change. The driving forces of the change that we expect, are fundamentally related to economic and social change. Large areas under tobacco and cereals are experiencing a severe economic crisis, especially in the hilly places, which are cultivated with increasing difficulty, with poor economic results and under the risk of erosion (Diodato *et al.*. 2009).

The new LUC will be the consequence of a complex and impetuous LUC that was well studied and analyzed in the past (Di Gennaro and Innamorato, 2005). The further changes that we expect, will take place in an area that has experienced a period of deep transformation in the last forty years, under the pressure of opposite forces, such as the unregulated urban expansion, the intensification and the specialization of agricultural production activities (Fabiani and Favia, 1990; I sistemi di terre della Campania, 2002; Di Gennaro and Innamorato, 2005). The areas that will undergo the land use change, are those that are no longer cost effective for food crops, such as the erosion prone areas under cereal production, in which the no-food crops would also have an environmental value (Fagnano *et al.*,2012 a).

The main driving forces of this process are related to economic factor and to the reduction in the number of farmers in some context, especially in the interior part of the region, far from the main cities. But in some context, there are other driving forces of the LUC. The first is that some areas are polluted due to illegal contamination or fallout of particulates and pollutants as a consequence of illegal burning of waste. The second is that some irrigated areas have problems of salinity, as a result of excessive withdrawal of groundwater. Considering the incentives for no-food energy crops, it is most likely that in short time some of these areas will be subjected to LUC.

No-food crops suitable in these contexts are the perennials, and the land use change would certainly lead to a positive impact of reducing erosion, but also on the reduction of nutrient requirement, fuel consumption and perhaps it would also lead to increased profitability.

Several studies have demonstrated that in the interior areas of Campania region, the rain erosivity is higher during the months of

September-October (Diodato *et al.*, 2009), which correspond to the period of maximum erodibility of soils also due to the traditional wheat cultivation technique, which provides for the absence of vegetation during these months. As a matter of fact, 80% of the annual erosion occurs during this period. In addition, the wheat yield in these areas is very low (yield value of about 2.5 t/ha/year). Consequently these crops do not seem to be sustainable, in the long term, from an economical and environmental point of view (Fagnano *et al.*, 2012b). No-food crops suitable in these contexts are the perennials and then the land use change would certainly lead to a positive impact of reducing erosion, but also on the reduction of nutrient requirement, on fuel consumption and perhaps an increase in profitability, if under a proper incentive mechanism.

With this background, the aim of this work is to identify the areas in which the land use change could be realistic and ecologically compatible and to evaluate the main consequences of the new land cover mainly in terms of erosion risk reduction.

Materials and methods

Area of study

The study area included the whole Campania region, because the Common Agricultural Policy boundary is the same as the administrative boundary and also because the habitat and topography, change largely due to changes in the surrounding regions. The total area of the territory is about 13,600 km^2, and is made up of mountains, 34.6%, hills, 51%, and plains, 15%. It was assumed that the areas that will undergo the land use change are the hilly cereal growing areas with altitudes between 400 and 750 meters above sea level.

One of the GIS layers used for the land use change study, was derived from the CORINE Land Cover (CLC). The land use map was filtered in ArcGis in order to select the non-irrigated cereal land (Figure 1). Moreover the hilly areas, from the height of 400 to 750 meters above sea level, were obtained by filtering the Digital Elevation Model (DEM) of the Campania region at 20 m resolution (Figure 2).

The eligible areas for land use change was identified by filtering the non-irrigated crop, with altitudes between 400 and 750 m a.s.l., excluding the National Parks, Site of Community Importance (SCI) and Special Protection Areas (SPA).

Climate conditions and suitable crops

The climate model was inferred from the Ground Water Protection Plan (PTA) of the Campania region. The climate in the study areas, can be approximated by the following linear functions:

Mean Annual Temperature = 16.5 - 0.006   height (m.a.s.l.)

Mean Annual Rainfall = 750 mm + height K_2

with K_2 = Coefficient that ranges from 0.40 to 0.70.

Therefore, according to the De Philippis's classification (1937), this area can be classified as 'cold Lauretum', which is a good for the *Arundo donax* crops up to 750 m a.l.s., with recoverable biomass yield in the order of 12.6 t/year after the third year. For hilly wheat areas, a yield value of 2.5 t/ha/year was considered.

Restrictions

The following shapefiles of Campania region were used for the selection of the areas to be converted: natural parks, protected areas (Figure 3), Site of Community Importance (SCI) (Figure 4) and Special Protection Area (SPA) (Figure 4). These layers were imported into ArcGIS in order to exclude them, since they are assumed non-con-

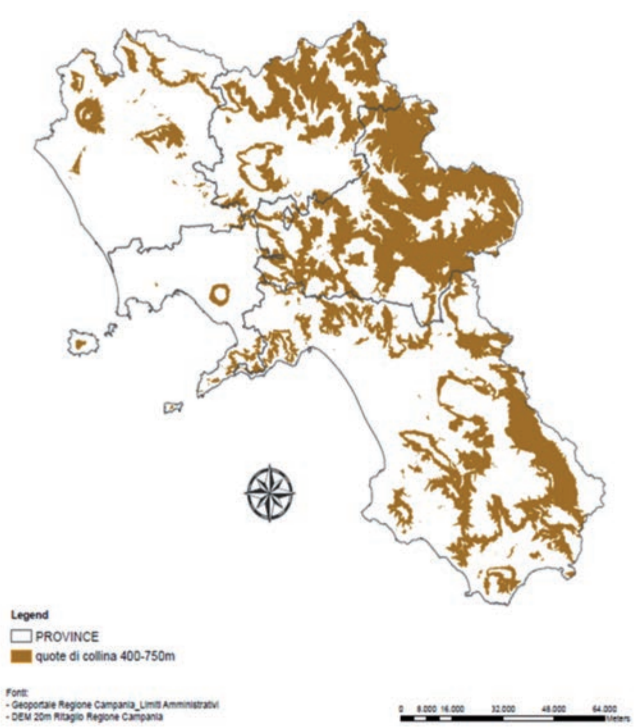

Figure 1. Hill areas, with altitudes between 400 and 750 meters above sea level (DEM of Campania).

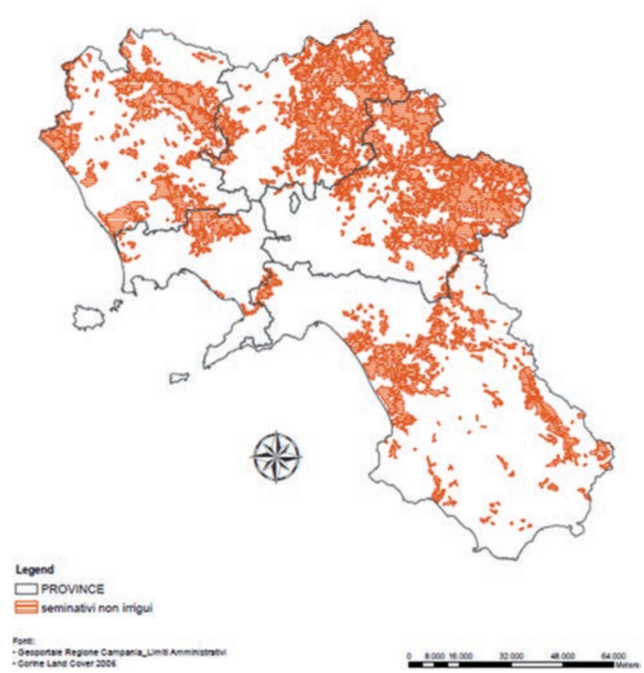

Figure 2. Areas cropped with cereals (CORINE Land Cover).

vertible to energy crops. It's important to note that future management of SCI and SPA could allow the land use change into biomass, but it is not certain, and at date it is correct to exclude these areas.

Soil erosion risk prediction

The soil erosion prediction map was evaluated using RUSLE equation, (Wischmeier, 1959; Wischmeier *et al.*, 1969,1971,1978; Summer *et al.*, 1998) which is not a physically based model, is:

$$A = 2.24\ R\ K\ L\ S\ C\ P,$$

where, A is the average annual soil loss (t/ha/year), R estimates the rainfall erosivity, K estimates the soil erodibility, L is the hill slope, S estimates the hill slope gradient, C is the ground cover factor and estimates the soil susceptibility to the erosive agents and P represents the effect given by any conservative practices of canalization or cultivation. For each parameter, an algorithm was suggested for application to the whole region.

In these areas, erosion has been estimated with the current land use (cereals) compared to the erosion that would occur if the land use were converted to permanent crop.

Methods for estimating the energy potential

The energy potential was predicted for both energy crop and straw, assuming that is possible to collect the straw for energy use

The energy potential of *Arundo donax*, is about 185,000 toe/year (toe is ton of oil equivalent), that was calculated assuming collection 42% of production with moisture content of 30%, with a lower heat value (LHV) for dry biomass of 17.6 MJ/kg. In the case of straw, the value is 70,000 toe/year assuming 90% of the production can be collected and moisture content of 15%.

Results and discussion

Filtering the maps of the studied territory, some areas were identified. For industrial use, only the areas in which it is possible to organize a chain are suitable for LUC. With this approach, using the ArcGIS software, seven large areas were identified. In these seven zones, the land use change with no food crops is possible (Figure 5), without affecting important agricultural land context. The areas identified are only partially convertible.

The total amount of recoverable biomass and its energy value was estimated as reported in Table 1 and Table 2. The total amount of cereals actually produced, the energy cost for mechanization activity and the fertilization requirement were also estimated.

The predicted land use change does not affect all the suitable land, that is 150,000 ha, but only a fraction of these are eligible.

A possible scenario is the one in which, approximately, one-third of eligible zone change land use in the medium term, obtaining a scenario like the one presented in Table 3.

According to this scenario, about 50.000 ha would be converted to energy crops, which is a remarkable surface (4% of whole regional surface of 13,600 km^2) but is quite small compared to Campania region's energy needs. In fact, the biomass production assessed has an energy value of about 160,000 toe/year, equivalent to about 1.5% of the regional energy needs, or only about 3.5% of the regional electricity demand.

Most results of interest are for the potential reduction of soil erosion risk and the reduction of fertilization and machining requirements.

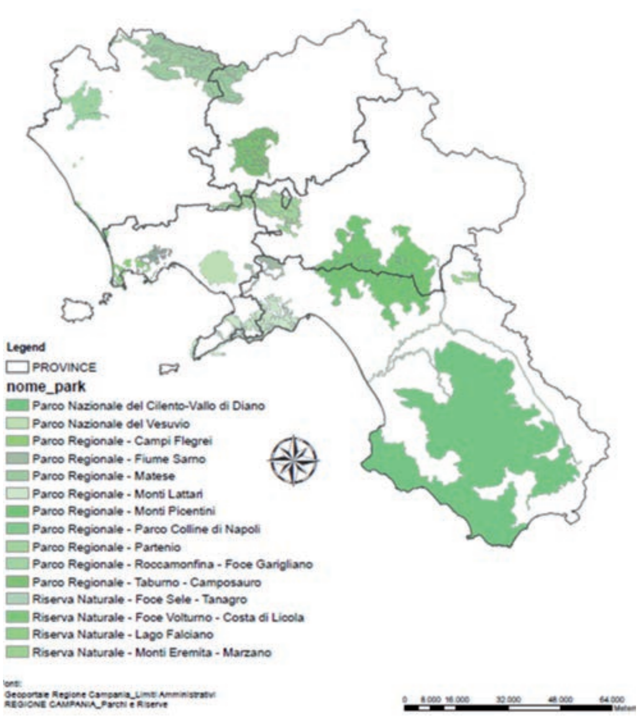

Figure 3. Natural parks and reserves.

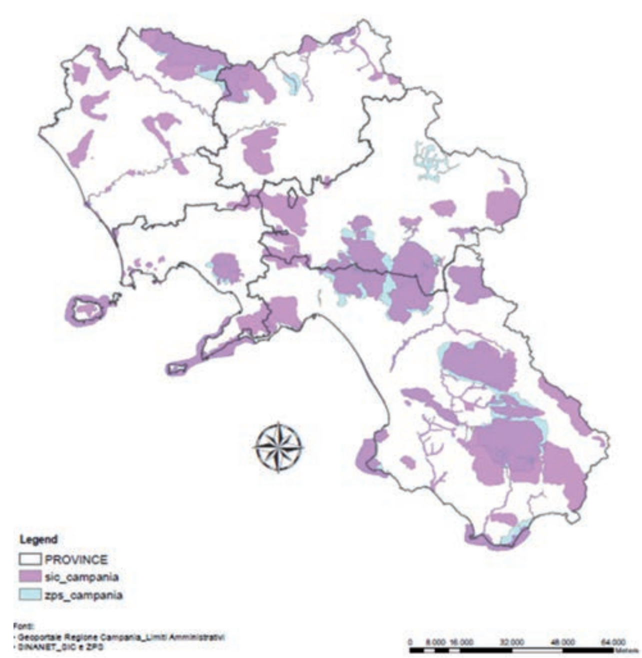

Figure 4. SCI and SPA.

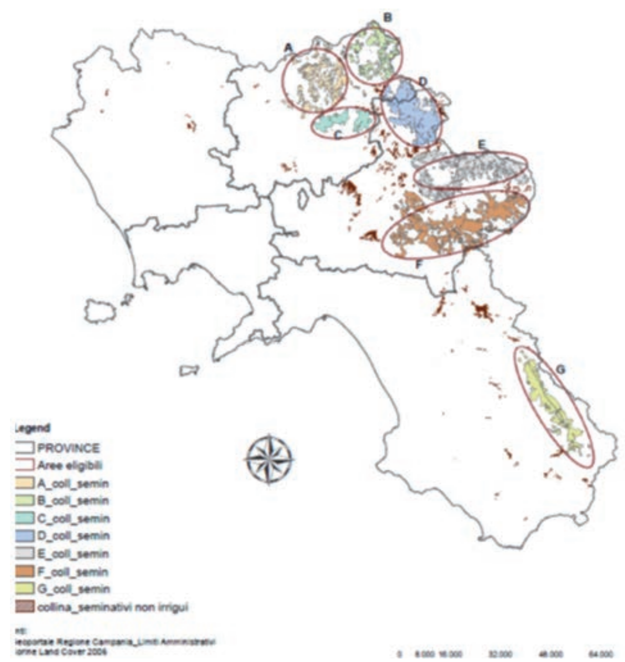

Figure 5. Macroareas resulting from the study.

Conclusions

It is possible to expect a large land use change into energy crops in Campania region. If the goal will be avoid overlap of biomass to arable lands, irrigated crops, parks and reserves, and other protected areas the eligible area remains only 1500 km². Of these 1500 km² it is reasonable to suppose a LUC of only 50,000 ha.

Measures aimed to increased land use change over this value, will lead to conflict with agriculture and environmental constraints.

In this scenario, even with this important LUC, the produced biomass, as an order of dimension, may only compensate the average increase in energy demand of one year in Campania Region.

Value of the biomass production, according to the hypothesis of this study, has been evaluated in the order of 25 million euro a year (assuming a unit price of biomasses of 30 €/t at the plant). This value has to be compared to the value of the actual wheat production, in the same areas. It would be 33 million euro a year (assuming a unit price of 270 €/t of wheat) and would appear more profitable but the production costs are far greater.

Considering the Land Use Change with *Arundo donax* there is a reduction in soil erosion in the order of 300,000 t/year that is one of the main goal of the LUC. This would lead to a saving, on a global scale, in terms of working and fertilization activities, in the order of 10 million tonnes of CO_2 per year.

Table 1. Comparison between biomass produced with actual land use (wheat) and the supposed new land use (*Arundo donax*).

	Zone A	Zone B	Zone C	Zone D	Zone E	Zone F	Zone G	Total
Surface of the eligible area (ha)	10˙446	73˙713	5˙209	15˙483	18˙046	19˙987	9˙497	152˙381
Straw availability (t/year)	13˙985	98˙683	6˙974	20˙728	24˙159	26˙758	12˙714	204˙000
Arundo donax availability (t/year)	122˙845	866˙865	61˙258	182˙080	212˙221	235˙047	111˙685	1˙792˙001
Available energy of straw (toe/year)	4˙867	34˙342	2˙427	7˙213	8˙407	9˙312	4˙425	70˙992
Available energy from *Arundo donax* (toe/year)	33˙905	239˙255	16˙907	50˙254	58˙573	64˙873	30˙825	494˙592

Table 2. Surface eligible for LUC, surface supposed interested to LUC and production, reduction of predicted erosion.

	Zone A	Zone B	Zone C	Zone D	Zone E	Zone F	Zone G	Total
Surface of the eligible area (ha)	10˙446	73˙713	5˙209	15˙483	18˙046	19˙987	9˙497	152˙381
Average of soil loss with wheat crop (t/ha)	3.51	8.938	3.83	4.89	2.968	6.796	1.555	
Average of soil loss with *Arundo donax* (t/ha)	0.47	1.19	0.51	0.65	0.40	0.91	0.21	
Predicted annual soil loss with wheat (t/year)	36˙697	658˙847	19˙950	75˙712	53˙561	135˙832	14˙768	95˙366
Predicted annual soil loss with *Arundo donax* (t/year)	4˙893	87˙846	2˙660	10˙095	7˙141	18˙111	1˙969	32˙715
Predicted soil loss reduction (t/year)	-31˙804	-571˙001	-17˙290	-65˙617	-46˙419	-117˙721	-12˙799	-862˙650

Table 3. Evaluation of the consequence of the land use change only a part of eligibile areas.

	Zone A	Zone B	Zone C	Zone D	Zone E	Zone F	Zone G	Total
Surface of the eligible area (ha)	10˙446	73˙713	5˙209	15˙483	18˙046	19˙987	9˙497	152˙381
Surface with LUC (1/3 of the eligible) (ha)	3˙482	24˙571	1˙736	5˙161	6˙015	6˙662	3˙166	50˙794
Estimated production of *Arundo donax* (t/year)	40˙948	288˙955	20˙419	60˙693	70˙740	78˙349	37˙228	597˙334
Total energy value of *Arundo donax*; change supposed in 1/3 of the eligible surface (toe/year)	11˙302	79˙752	5˙636	16˙751	19˙524	21˙624	10˙275	164˙864
Potential reduction of soil losses (t/year)	-10˙601	-190˙334	-5˙763	-21˙872	-15˙473	-39˙240	-4˙266	-287˙550

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