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STRATEGIES FOR RECLAMATION OF AREAS COVERED BY DWARF PINE

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Abstract: *Uncontrolled development of natural afforested areas might represent a problem by itself, often implying loss of cultural landscapes and habitat variety, bio and eco-diversity depletion, territorial homogenization with loss of economic and natural resources. In the northern area of the Altopiano dei Sette Comuni, a plateau area in the Venetian Alps, dwarf pine has been the most invasive specie, with an high impact in the occupation of alpine pasture land, road, paths and historical sites.*
In this work a strategy to contain the spreading of this specie along the forest road network is analyzed. The analysis considers the operative costs for both felling and transport of dwarf pine stems to intermediate landings. The logistic problem has been widely analyzed by a GIS based decision support system based on network analysis model and assuming different scenarios considering different level of upgrade of the forest road network. Supply-cost curves have been then constructed to analyze the total reclamation cost in terms of quantities of wood material.
The study shows that on the one hand the invasion of forest roads represents a growing problem and on the other hand it highlights that the operative costs are high. The supply-cost actually ranges from 52 € t^{-1} to 143 € t^{-1} and it decreases, ranging from 52 € t^{-1} to 107 € t^{-1}, only if the upgrade of the forest road network is concerned.

1. Introduction

Low-intensity agricultural practices such as grazing play a significant role for nature conservation in Europe. Many nature-like areas are in fact the product of some human influence and the conservation of this areas depends entirely on the continuation of this influence (Ostermann, 1998).
Nowadays the uncontrolled encroachment of forests might represent a problem by itself, often implying loss of cultural landscapes and habitat variety, bio and eco-diversity depletion, territorial homogenization with a loss of economic and natural resources (Conti et al, 2004).
Shrub invasion into subalpine pastures mediated by abandonment and livestock reduction is a common process in the Northern Calcareous Alps (Dirnböck et al. 2008). Especially dwarf pine (*Pinus mugo*) is able to effectively invade subalpine and alpine non-forest sites (Dirnböeck et al. 2008; Dullinger et al. 2003).

The abandonment of traditional grazing activities would lead to a change and reduction of valuable habitat types (Ostermann, 1998) and to a biodiversity loss (Watkinson et al. 2001; Tallowin et al. 2005; MacDonald et al, 2000; Pornaro et al, 2009).

It is demonstrated in many studies (Lindstöm et al., 1998; Zbinden et al. 2003; Zeitler, 2003) that the management of alpine pastures is a key factor for preserving most of the present black grouse (*Tetrao tetrix*) habitats. Black grouse habitat capacity depends on pasture management practices such as grazing, mowing, and control of regenerating tree and shrubs. Declining use and maintenance of alpine pastures leads to declining black grouse populations (Glänzer, 1985).

In addition to the impacts on bio and eco-diversity, other negative effects are caused from uncontrolled dwarf pine expansion, such the invasion of historical sites and the occlusion of forest roads and trails. The vegetation, if not controlled, may stop the vehicle traffic precluding the accessibility of the areas. A decline in the landscape's accessibility and the progressive loss of penetrability will affect the touristic exploitation of the area with a depletion of the environmental services, and will make problematic the correct management of the area.

In this paper a first approach for the reclamation of an area invaded by dwarf pine is analyzed assuming the removal of the trees on two strips along the borders of the forest roads. This sort of maintenance could be considered as area starting point that can be followed by removal operations also inside the dwarf pine stands or on the border between pastures and the forest.

1.1 Aims

1. Analyze the actual situation in the case-study area, in particular regarding the dwarf pine areas and the forest road network characteristic and evaluating the needs for reclamation

2. Hypothesize a strategies of reclamation and maintenance of the forest road network and evaluate the operative costs.

3. Material and methods

3.1 Study area

Study area is placed in the northern part of the Altopiano dei Sette Comuni in North-eastern part of Italy (latitude (N) of 46 – 45.92 longitude (E) of 11.45 – 11.65). The altitude ranges from 1 600 m to 2 341 m a.s.l. The area is designated as Special Protection Area (SPA code IT3220036) in the Natura 2000 Network under the Habitats and Birds Directives. Tree vegetation consists in large part of a sparse forest of dwarf pine.

For centuries, the northern part of the area has been grazed by sheep and cows in the summer (June-September). In 19^{th} dwarf pine was constantly used for the production of charcoal (Zovi, 2009).
The Altopiano dei Sette Comuni represents a meaningful case study for the effect of the expansion of dwarf pine forest over pastures, breeding area and historical sites, mainly represented by the remain of the First World War.

3.2 Layout of the study

The study can be divided into five steps (Figure 1). Firstly a preliminary investigation of the area considering the precise definition of the surface covered by dwarf pine, and the study of its main characteristics (growing stock, structure) have been done. Forest road network has been also analyzed defining the part directly involved in the transportation of wood material derived from dwarf pine utilization and the part invaded by dwarf pine. According with the characteristic of the area the most suitable operative strategy and the relative working cost have been defined. To determine the felling productivity and cost some field trials have been carried out.

The following analysis includes step four and five, in which the availability of material at road-side have been defined, the transportation of the material has been modeled and the logistic and the organization of the operations have been studied assuming different scenarios and different solutions.

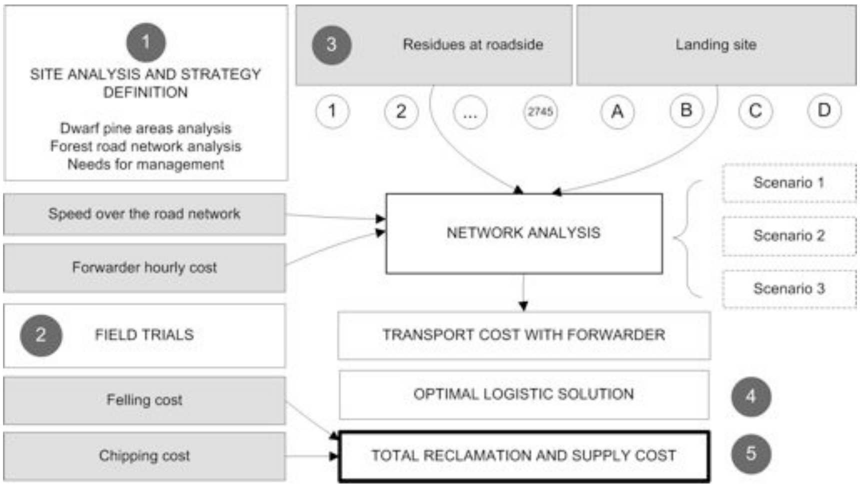

Figure 1. Layout of the study

3.3 Site analysis and needs for management

The extension of the areas covered by dwarf pine in the northern part of the Altopiano dei Sette Comuni has never been so wide as today, and has become a major problem in the last decades. The expansion is continuous and uncontrolled, with an increase of dwarf pine areas being estimated in 494 ha in the last 40 years.

A detailed survey of the area has been done in order to know the situation and assume the correct "modus operandi". The major problem actually arises on pastures and on forest road. Forest road represent the only way to access the area and the maintenance interventions to prevent the invasion of the road side are considered to be the priority, in order to make possible, afterwards, the fulfillment of other kinds of intervention.

To estimate the characteristic of the dwarf pine formation and then the dependent cost of intervention five plots area (15m x 15m) have been settled chosen randomly over the study area. All individuals of dwarf pine in each plot have been sampled, recording for each individual the number of stems and the diameter of each stem. Afterwards each plot has been clear-cut, all the wood material has been weighted and the mean growing stock has been determined.

The extension and the characteristic of the forest road network have been also surveyed. The area shows a considerable density of roads due to the fact that Altopiano dei Sette Comuni Plateau was affected by the events of WW1 and battles followed one another for three years. The study area was divided by the battle front which remained stable during all the war; to supply the opposed armies a diffuse road network was built on both the sides of the front and it still maintains its efficiency.
GPS survey has been settled to collect information about dimensional characteristic (transit classification), limiting width (transit barriers) and roads susceptible to be invaded by dwarf pine.

3.4 Logistic organization

One of the major constraints in the reclamation and correct management of the areas are the high operative costs. In other words to maintain in good condition the pasture areas and the forest roads it is necessary to invest a lot of time and money without any apparently economic benefit.

A considerable proportion of the total cost originates from the logistics activities (transportation, storing and handling) that are particularly difficult in that condition. Productivity and cost of transportation depend on several factors, such the type of material, the type of hauling vehicle used and the characteristic of the road network (Pottie and Guimier, 1986). Logistic chain modeling is very important in improving the overall performance of the total logistic chain (Slats et al., 1995). The logistic chain considered in the case study is represented in Figure 2.

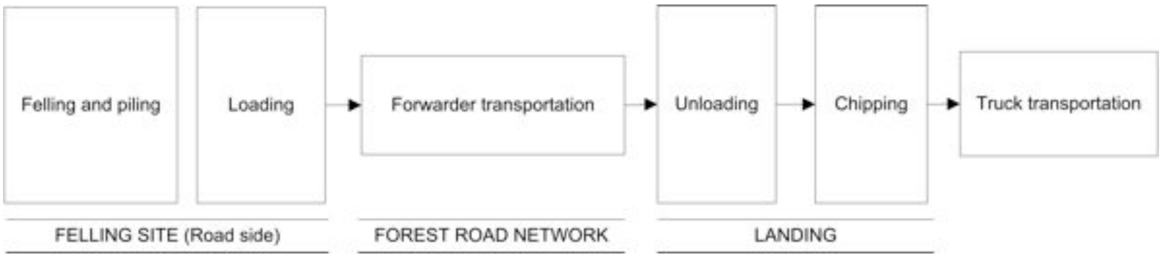

Figure 2 Considered logistic chain

The three most important frames in the organization of the operation are the pile of material on the road side (directly connected with the dwarf pine areas location), the forest road network and the landings (Figure 3). Distance between each felling site (FS) (in meters) have been calculated using the following formula

$$FS = \left(L\max \times \frac{1}{GS} \right) \times \frac{1}{LD} \qquad [1]$$

Where:

GS, mean growing stock of the dwarf pine areas (in t m^{-2})
Lmax, carrying capacity of the forwarder in transporting branches (t) (limited to 4 t because of volume limitation)
LD, lateral distance reachable by the forwarder crane (m) (assumed equal to 7.5 m on each side of the road).

According to this assumption and considering the growing stock of the dwarf pine in the area, the necessary distance along the road to complete a load results 20 m. This is the length between each felling site considered in the analysis.

Potential landing sites (LS) have been detected through site analysis over the area. A potential landing site should have suitable dimension for piling and chipping the material and should be easily reachable by trucks for final transportation.

3.5 Scenario simulation

To choose the best logistic solution that minimizes the total operative cost a scenario simulation has been carried out utilizing a Geographic Information System (ArcGIS 9.3). The use of GIS can be seen as a Decision Support System (DSS) which integrates spatially referenced data in a problem solving environment (Borrough et al. 1998).
ArcGIS Network Analyst tool allows creating an origin–destination (OD) cost matrix from multiple origins to multiple destinations. An OD cost matrix is a table that contains the network impedance (such travel time) from each origin to each destination. Additionally, it ranks the destinations that each origin is connected to in ascending order based on the minimum network impedance required to travel from that origin to each destination. ArcGIS Network Analyst provides a vehicle routing problem solver that can be used to determine solutions for complex management tasks and allows setting a series of descriptors (speed limit) and restriction (barriers) to modeling the transport on a road network. The routing solvers OD cost matrix is based on the Dykstra's algorithm (Dykstra, 1984) for finding shortest paths (ESRI, 2009).
The best network path is discovered for each origin (FS) – destination (LS) couple in order to find the cost to reach the closest destinations from each origin.

Scenario simulation considers three different situations, representative of the effect of the progressive upgrading of forest road network. *Scenario 1* represents the actual situation. *Scenario 2* tests the influence in the model of the construction of a new forest road (Figure 3) that will reduce considerably the mean transport-distance. Finally *Scenario 3* tests how the transport cost will change through a total upgrade of forest road network, removing all the transit barriers.

3.6 System of utilization and cost analysis

Felling and piling

The only effective way to fell dwarf pine is motor-manually using a chainsaw because the characteristic of the stem does not allow using any other system. Felling cost (Table 1) has been derived from time-study on the felling operation into 5 study plots. The reclamation strategy plans to fell all the material within 7.5 m from each border of the forest road, being this distance easily reachable by the crane of the forwarder which stays on the road.

Forwarder transportation modeling

For the extraction of the material it is supposed to use a forwarder. The possibility to fast the loading and unloading operation, the high carrying capacity and the high speed and mobility on the forest road network highlights the convenience in using this machine.
Driving time from felling sites to landings was calculated in ArcGIS with Network Analyst tool. Different average driving speeds for the forwarder were assigned according to the characteristic of the road.
Transportation cost was then calculated based on time needed for covering the route from the felling site to the landing, multiplying for the forwarder's hourly cost.
The hourly cost of the machine has been determined applying the Miyata's method (Miyata, 1980) and using data provided by a forest enterprise using forwarder in the studied context (Table 1).

Chipping

Chipping at landing is supposed to be done using a mobile chipper (truck mounted) immediately after the felling and extraction operation to preserve the essential oils contained in the wood material. The chipping productivity and cost (Table 1) are derived from some field trials performed in chipping of tree branches (Negrin, 2010).

Table 1. Operative cost

Operation		
Felling	*€ t^{-1} (w=50%)*	11.8
	€ ha^{-1}	1633
Chipping	*€ t^{-1} (w=50%)*	14.7
	€ ha^{-1}	2034
Forwarder transportation	*€ h^{-1}*	121

4. Results and discussion

4.1 Forest road network situation and maintenance needs

The forest road density index referred to the area occupied by dwarf pine is 19 m/ha, a considerable value for an area without particular productive vocation. Mean road width is equal to 2.8 m and the limiting transit barriers are represented manly by harpin turn and sporadic landslide point.

The part of forest road network used for dwarf pine transportation resulted about 37 km (Figure 3). Road classification considers two categories: roads suitable for trucks transit (24 km) and roads suitable only for forwarder transit (13 km). The forest roads suitable only for tractor transit have not been considered here because not involved in the utilization process.

The part of the forest road network susceptible to be invaded by dwarf pine is about 21 km. Some of these roads are already completely occupied by dwarf pine (Figure 4).

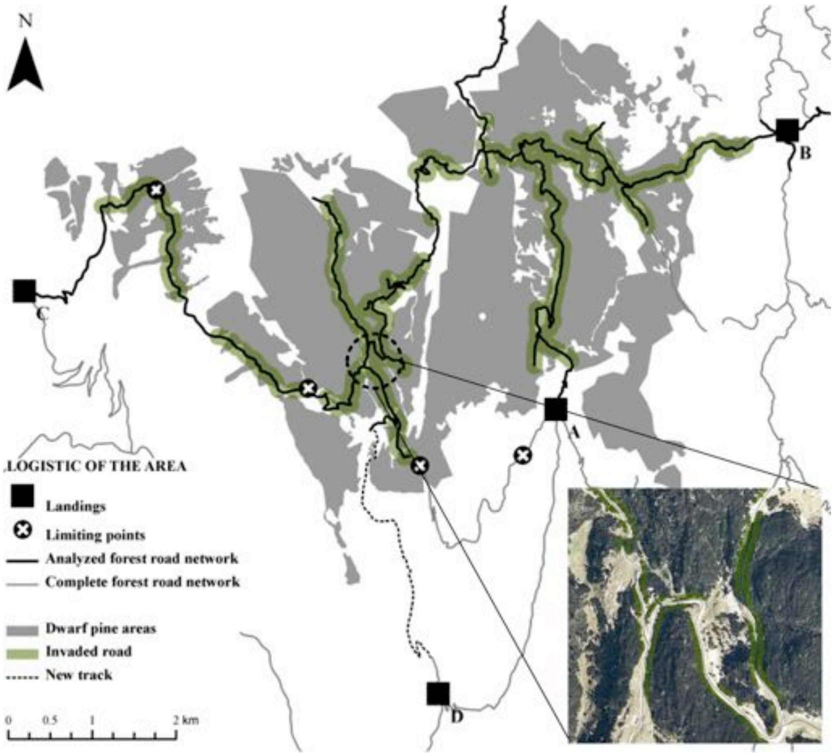

Figure 3. Analyzed area and road maintenance needs

a) b) c)

Figure 4. Actual condition of forest road. a) susceptible to invasion; b) partly invaded by dwarf pine; c) completely occupied by dwarf pine

4.2 Extension and characteristic of areas invaded by dwarf pine

The surface covered by dwarf pine formation resulting from aerial-photo-interpretation is 1867 ha.
Data about the analysis inside the study plots are represented in

Table 2 and show a mean growing stock of 138.4 t ha^{-1}.

Table 2. Sample plot data

	D_m	H_m	T_m	Mass per surface unit
	cm	m	t	t ha^{-1}
Plot 1	8.1	2.81	3.04	135.1
Plot 2	7.7	2.63	3.3	146.6
Plot 3	8.7	2.84	3.74	166.2
Plot 4	7.1	2.52	2.64	117.3
Plot 5	7.6	2.67	2.85	126.6
Mean	**7.84**	**2.69**	**3.11**	**138.4**

D_m = mean diameter; H_m = mean height; T_m = total mass.

The strategy for the reclamation of the forest road side areas regards potentially a surface of 25 ha. The felled material is in this case about 3323 t (w=50%).

Considering the limiting transit barriers on the forest road network the material retrievable and transportable at the landing sites in the actual situation is 2985 t (w=50%).
The supposed rotation time is 25 years (Broll et al. 2009) with a planned felling area of about 1 ha per year and a harvested mass per year of about 138 t.

4.3 Operative cost

The cost for felling and piling the material resulted equal to 1 633 € ha^{-1}. The total cost to intervene over all the forest road network leaving the material on road side is equal to 40 825 €. Considering a further processing of the wood material (i.e. essential oils distillation), the transport cost from the felling site to the landing point and the chipping cost must be added. Through addition of felling, transporting (included loading and unloading) and chipping costs, the total cost of woodchips can range from 52 € t^{-1} to 143 € t^{-1} in the actual situation with an average cost of 92 € t^{-1}. The best solution would be the activation of two landing sites in point A and point B. Nevertheless cost could be considerably reduced through the activation of a third site in point D. This implies the construction of a new road (**Figure 3**) that will permit the forwarder to avoid the outflanking of a mountain that would result tactical.

The average total cost in Scenario 2 then decreases to 68 € t^{-1} ranging from 52 € t^{-1} to 107€ t^{-1}. The upgrading of all forest road network makes possible to add another landing site in point C. The elimination of transit limiting points allows an increase in the available material up to 3323 t but does not affect significantly the transportation cost. In Scenario 3 the average cost becomes 65 € t^{-1} ranging from 52 € t^{-1} to 107 € t^{-1}.

Figure 5 displays the cost supply curves resulting from the hypothesized logistic solution for the different Scenarios. Each point of the cost-supply curve gives the average cost per ton to supply different level of chipped material. The reclamation of the area (20 ha) accessible in the actual situation costs about 500 000 € (including transport at landings and chipping). Through the building of a new forest road the total cost decreases to 385 000 €. Upgrading all the forest road network reclaimed surface increases up to 25 ha with a total cost of 444 000 €.

The data obtained from Regional Forest Service (Regione del Veneto, 2008) on the construction of forest roads during the period 2000-2006 indicates that the construction cost of a new forest road is on average 38.5 € m^{-1}. The intervention to update an highly debased forest road is about 15 € m^{-1}. The total cost to activate the new forest road, settled up an existing track for a distance of 1.7 km and constructing a new track 2 km long is estimated in approximately 95 500 €.

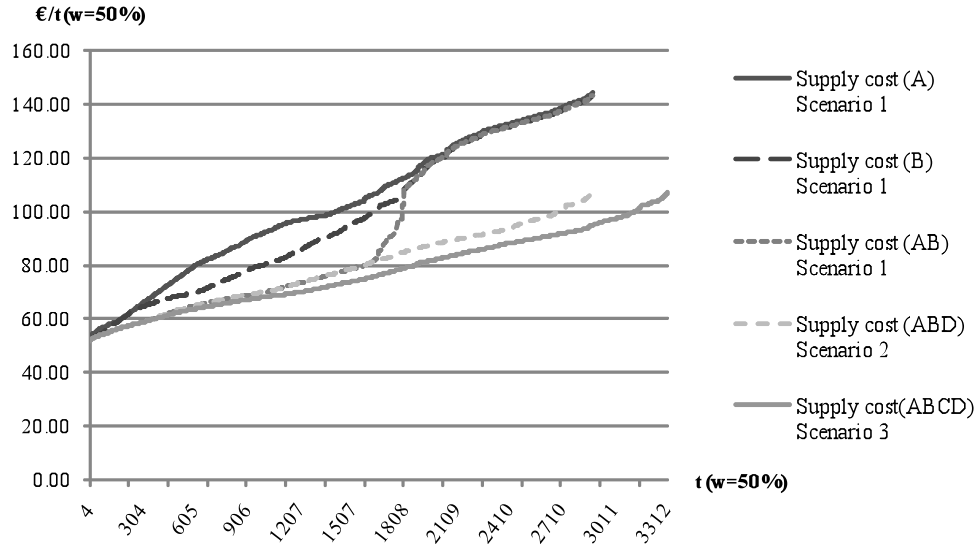

Figure 5. Supply-cost curves for different logistic scenarios;

5. Discussion and conclusion

The work carried out is just the first approach for the reclamation of areas that have been interested by the growing of dwarf pine. The felling of the areas along the road side seems to be the priority in order to maintain in a good status the condition of the forest road network, that represent the access point for all the next reclamation interventions that could be planned in order to provide positive effect in terms of touristic exploitation and aesthetic value.

It has been highlighted that the fast expansion rate of dwarf pine is creating a serious problem in the study area. This invasion trend has to be stopped, considering that most of the benefit bringing from the intervention (bio and eco-diversity benefit, social and aesthetic benefit) are not easily valuable in economical terms.
One of the purposes of the European Landscape Convention is to encourage public authorities to adopt policies and measures for protecting, managing and planning landscapes throughout Europe so as to maintain and improve landscape quality (Council of Europe, 2000).

Despite this nowadays the intervention for reclamation of those areas are limited, with the constraints of the high operative cost, for the costly and time consuming process. For that reason the improved areas are very small and made mainly from hunters on volunteer basis or from the farmers directly involved in pasture management.

Actually financial measures such as subsides, incentives or compensation payments, that represent the main tools so far adopted by European Union, as well as by national and regional governments, in order to counteract marginalization trends and land abandonment, seems to be not sufficient.

The analysis confirms that the operative cost are high, especially considering that work at road-side is the simplest situation. To remove dwarf pine trees also from the pasture's border or to maintain suitable habitats for black grouse it must be considered that recovering costs will increase proportionally with the distance from the road. A proposed solution to overcome the economic constraints would be to find an alternative use of the material.

Through the analysis of other experience the final destination of the material could be the production of chips for energy and the production of essential oil for pharmaceutical use. The two activities are complementary and the essential oils distillery could utilize the material in two successive steps with a multiple valorization of the final product. This hypothesis finds support in the experience carried out in some areas in Südtirol region, where this system of production seems to work, bringing economic, environmental and landscape benefits (Broll et al. 2009).

The supply cost ranging from 52 € t^{-1} to 143 € t^{-1} makes the wood-chips not competitive on the market. Even the amount of 138 t y^{-1} seems to be not enough for the energy exploitation. Rather interesting is the possibility to use the material in the essential oils production, considering both the high selling price of the product and the necessity of lowest quantity of material in the production process. Broaden economical analysis should be carried out on this aspect.

The final step should be to activate a long term management plan involving all the stakeholders (hunters associations, farmers, tourism associations, historical associations, wildlife ecologists) considering all the economic and environmental consequences and opportunities related to the present evolution of the landscapes.

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