SWOT-AHP Dynamic Approach to Define Medium Term Strategies to Develop Forest Quality Chain and Forest Energy Chain in Tuscany

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Sommario

Lo scopo dello studio è diretto a definire delle strategie di medio-lungo termine che si concentrano sul miglioramento qualitativo e quantitativo delle produzioni di legno della Toscana, garantendo una redditività ai lavoratori forestali e la rivitalizzazione dei boschi di qualità. L'approccio proposto si basa su una SWOT dinamica e analisi gerarchica: i criteri dell'analisi SWOT-AHP sono stati esaminati in considerazione tre diverse situazioni: quella esistente, di medio e di lungo termine. L'applicazione ha portato alla definizione di analisi strategiche estremamente efficaci. In questo caso l'utilizzo di un modello dinamico, in grado di quantificare la rilevanza di ciascun componente, conferisce ai beneficiari finali uno strumento esaustivo per la pianificazione territoriale.

Abstract

The aim of the study is directed to define medium-long term political strategies that focus on the qualitative and quantitative improvement of the Tuscany wood productions, at the same time guaranteeing a profitability to the forest workers , as well as revitalization of the quality woods productions. The proposal approach is based on a dynamic SWOT-AHP

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analysis: the criteria of the analysis have been examined considering three different situations: the existing one, medium and long term scenarios.

This integrated application led to the definition of extremely efficacious strategic analyses. In this case the formalization through a dynamic model, able to quantify the relevance of each component, gives to the final beneficiaries an exhaustive tool for territorial planning.

Keywords

Dynamic SWOT; AHP analysis; wood production; participatory approach; governance of forest; forest chain

1. Introduction

The Tuscan forest-wood chain is characterized by the lack of a physical connection between the internal forest resources and the processing wood companies (furniture and woodworking firms, etc.). This discontinuity is mainly due to the low quality of the regional forest productions, which are mainly focused on firewood from coppice (turkey-oak and pubescent-oak – 75÷85% of the production); on chestnut for lumber, tannin and post; on conifers, as Douglas fir and silver fir, for lumber and pulp wood; on pine forest for wood packaging (Casini, 2008). This situation determined a strong dependence of the local wood processing enterprise on the foreign lumber (Marinelli et al., 1993). The low quality of the productions, the structural weakness of the wood harvesting enterprises are also to be considered too in this context. Finally, the lack of professionalism of the forest chain enterprises, is not able to guarantee a steady supply of the wood products (Fratini, Riccioli, 2009).

These aspects are therefore the reason behind the non-competitiveness of the local productions with respect to the foreign production, the latter being characterized by a strong lower prices and regularity of supply. This is also due to the lack of a Common Agriculture Policy coupled with a specific tool for supporting forest activities (Bauer, Corredor 2006).

In relation to this situation, it is fundamental to define medium-long term political strategies that may favour the qualitative and quantitative improvement of the local wood productions, at the same time guaranteeing a profitability to the forest workers during the transitional phases, as well as revitalizing the quality wood productions.

For this reason, a direct survey has been undertaken, in order to verify, in a specific area, the local resources, both in terms of forest and

entrepreneurial resources, and detect the strengths and weaknesses of the chain; and to examine uncontrollable external factors, like the wood market and its relationships with the territory. A SWOT-AHP analysis (Strength, Weaknesses, Opportunities and Threats through Analytic Hierarchy Process) method, underpinned by a participatory approach, has been implemented, in a dynamic way, to address this issue (Kurttilaa et al. 2000). In order to do so, the criteria of the SWOT-AHP analysis have been examined considering three different situations: the current, the mid-term, and the long term scenarios. The future scenarios have been defined considering the implementation of appropriate political strategies functional for the overcoming of the difficulties identified in the current scenario. In this way, a probable path for the development of the local economy was defined.

2. Methodological framework

In the current situation of strong market globalization, resuming the forest-wood chain enterprises, means, understanding and responding to the needs and requirements of the potential customers, as well as the opportunities and threats offered by the environment: economic trends, national and international legal framework, available technologies, etc.

For this reason, a particular attention to the examination of the external environment is needed, that is the set of forces and trends that cannot be controlled by the enterprises of the forest wood chain. Kotler (1986), refers to six reasons regarding the nature of these forces: demography, economy, physical limits, technology, as well as political-institutional, and socio-cultural aspects. Additional aspects can be identified for enterprises to effectively intervene over: the choice of the suppliers, the definition of the marketing plans, the choice of the distribution channel and thus of the intermediaries, the choice of the customers, considering both consumers or other companies, as well as the opinions of the interest groups (environmentalists, local communities, etc.), and of the public.

However, the real implementation of a strategic planning process, linked with the forest-wood chain, needs to go through a set of subsequent activities. These activities must take as references: the evidences of the sector, and the capacities of the current productive structures operating in the market: this will allow orienting the companies' activities.

S.W.O.T.[1] analysis is a methodology allowing the joint examination of both external and internal environmental aspects that impact on a system. This analytical tool allows the introduction of a systemic approach to the decisional processes (Kotler, 1986; Hemmi, 1995; Kurttilaa et al. 2000). This analysis is therefore able to synthesize the information with regards to the four dimensions and to determine the issues to be considered. The strengths and weaknesses are referred to the internal stakeholders of the chain that is those that can be controlled and managed with the entrepreneurial skills. The opportunities and threats, instead, are referred to stakeholders that are external to the companies of the chain, factors that cannot be controlled and managed with the entrepreneurial skills.

The method has been adopted and adapted for the identification of strategic actions that the public administration should implement in order to favour the development of the forest-wood chain in the long period. The long period perspective of the problem at hand, required the development of an analytical approach of the SWOT model that allows to evaluate the effects of the strategic actions proposed in the present and in the medium term. For this reason, a dynamic model of SWOT has been developed (Dealtry, 1992). In the case study, three series of SWOT analyses in succession have been developed, considering three scenarios: present time, medium term and future (Eq. 1). For the two future scenarios, also the effects determined by the strategic actions implemented by the public administration in the previous scenarios were taken into account:

$$SWOT^{t} = f(SWOT^{t-1}, a_{t-1}) \qquad [1]$$

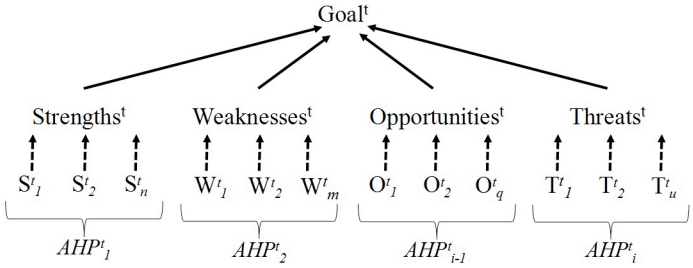
where
$t=\{1,2,3\}$
1 = present time
2 = medium term time
3 = future time
$SWOT^{t-1}$ = SWOT analysis done at moment t-1
a_{t-1} = strategic action done at moment t-1 as an effect of result of $SWOT^{t-1}$

Moreover, in order to quantify the phenomenon in respect to the three scenarios, a participatory approach was also implemented. It was based on consulting local stakeholders and on carrying out an Analytic Hierarchy Process (AHP) (Saaty, 1977, 1980; Kurttilaa et al. 2000; Wickramasinghe,

[1] Acronym for *Strength, Weakness, Opportunity, Threat*.

Takano, 2010; Gőrener et al., 2012). Widely used in the decision problems (Romano et al., 2013; Cozzi et al, 2014, 2015), the AHP method allows defining the priority/relevance order assigned by the stakeholders to the different factor (threats/opportunities and strengths/weaknesses) with respect to the aim of developing the local forest-wood sector (Fagarazzi et al., 2003; Rauch, 2007). Accordingly, it was possible to define the strengths/weaknesses factors and the threat/opportunities factors not as a simple list of numerous variables (size of the resources, availability of infrastructures, legal opportunities, etc.), but instead as "relevance" of each of the variables in influencing the examined strategic factor (Kurttilaa et al. 2000; Wickramasinghe et. al., 2010; Gőrener et al., 2012). This means that, through the AHP, the problem of *ranking* the variables was taken into account, by using an importance order or a preference order, on the basis of quantitative evaluations.

Figure 1 Hierarchical structure of SWOT analysis at t time



where:

$Goal^t$ = target at time t

n, m, q, u = respectively number of Strengths, Weaknesses, Opportunities, Threats factors

S^t_n W^t_m O^t_q T^t_u= respectively Strengths, Weaknesses, Opportunities, Threats at time t

AHP^t_i = AHP of i Aspects at time t

$i = \{n,m,q,u\}$

The contribution of each factor is quantified in relation to all the factors that combine to define the relevance of each aspect (*Strength*, *Weakness*, *Opportunity*, *and Risk*). Consequently, a matrix of pairwise comparison was built to for each aspect assessed (figure 1, equation 2) (Saaty, 1977, 1980; Kurttilaa et al. 2000, Shrestha et al. 2004).

Information derived from pairwise comparisons can be represented as a reciprocal matrix of weights, where the weight enters into the matrix as an element a_{ij} and reciprocal of the entry $1/a_{ji}$ goes to the opposite side of the main diagonal, where rows indicate ratios of weights of each factor with respect to all others (Eq.2). In the matrix, when $i = j$, then $a_{ij} = 1$. The value of weight w_i may vary from 1 to 9. The value 1/1 indicates equal importance while 9/1 indicates absolute importance (Saaty, 1977, 1980, Shrestha et al. 2004, Kurttilaa et al. 2000).

$$\boldsymbol{A} = (a_{ij}) = \begin{bmatrix} w_1/w_1 & \cdots & w_1/w_n \\ \vdots & \ddots & \vdots \\ w_n/w_1 & \cdots & w_n/w_n \end{bmatrix} \qquad [2]$$

When we multiply matrix $\boldsymbol{A}$ by the transpose of the vector of weights $\boldsymbol{w}$, we get the resulting vector $n\boldsymbol{w}$, then:

$$\boldsymbol{Aw} = n\boldsymbol{w} \qquad [3]$$

where $\mathbf{w} = (w_1; w_2; \ldots ; w_n)$ and n is the number of rows or columns. Further, Eq. (3) can be rewritten as:

$$(A-nI)\, w = 0 \qquad [4]$$

where:
n = largest eigenvalue, λ_{max}, or trace of matrix $\boldsymbol{A}$
$\boldsymbol{I}$ = identity matrix of size n.

Saaty (1977) demonstrated that $\lambda_{max} = n$ is a necessary and sufficient condition for consistency. Inconsistency may arise when λ_{max} deviates from n due to inconsistent responses in pairwise comparisons. Therefore, the matrix A should be tested for consistency using equations (Saaty, 1993; Mawapanga et al., 1996, Shrestha et al. 2004):

$$CI = (\lambda_{max} - n)/(n-1) \qquad [5]$$

$$CR = CI/RI \qquad [6]$$

where:

CI = consistency index
RI = random index generated for a random matrix of order *n*
CR = consistency ratio.

The general rule is that $CR \leq 0.1$ should be maintained for the matrix to be consistent. Homogeneity of factors within each group, smaller number of factors in the group, and better understanding of the decision problem would improve the consistency index (Saaty, 1993). The structure of the SWOT analysis, linked with the sector of the forest productions, could be represented as a set of phases that can be synthesized as follows:

a. *PEST analysis*, (Political, Economy, Sociology and Technical analysis), directed to identify the current situation of the market and the factors that play a role in it (subsection 4.1);
b. *SWOT-AHP analysis* (subsection 4.2) where *SWOT analysis*, oriented to the joint evaluation of the positive and negative factors which are present internally and externally in the market of the wood products and A*HP,* used to determine the "relevance" of each variable influencing the examined strategic factor and the relative importance of each strategic factor compared to the other;
c. *Map Knowledge development*, used to develop a set of cognitive maps which compare strengths to weakness and opportunities to threats (subsection 4.3). These maps summarize clearly the results obtained by carrying out three SWOT scenarios, highlighting which could be the dynamics for the local chain.

3. Case Study

The Tuscan Valtiberina area is located in the Northern-East part of the region of Tuscany. It belongs to the Tiber basin and its geo-lithological characteristics belong mainly to the marley-arenaceous formation. Valtiberina is a territory characterized by a high tree density index (60%), mainly covered with forest standings of a high typological variability, in which hard-wood forests prevail (82%), than soft wood with only 4% of forest surface. The most represented species are turkey-oak and pubescent-oak, including a great quantity of sporadic forest species (Acer sp.pl., *Fraxinus excelsior* L., *Fraxinus oxycarpa* Bieb. *Laburnum anagyroides* Medicuslo – maggiociondolo, *Prunus avium* L., *Tilia sp*.pl., *Taxus baccata* L.).

4. Results and discussion

4.1 PEST Analysis

In order to evaluate the different aspects characterizing the PEST analysis, both publications which examine in depth issues linked with legal and socio-economic aspects, and specific indexes derived from questionnaires to privileged witnesses of the primary sector and of the territorial planning, have been used.

4.1.1 External factors - political, economic, social and technological

Political factors are based on the implemented regulatory instruments favour the development of the forests' sporadic species and the development of the wood-energy chain; that is a chain able to sustain, in the transition phase, the management costs of the silvicultural activities to improve the quality of the Tuscan woods. Some of political and regulatory aspects favour the growth of the forest biomasses' market for energetic purposes such as "Biomass Action Plan" (COM/2005 628), Law 448/1998, Law March 11th, 2006 n. 81, Law December 4th, 2007 n. 244, Guarantee Fund – Tuscan Region, and measures 125, 311 and 321 of Rural Development Plans (RDP 2007-2013Tuscan Region. Other regulatory factors favour the managing of the woods and the improvement of the quality and of the species such as DPR 124/2002 ("decreto salvaboschi), Regional Law 39/2000 "forest law of Tuscany" or measures 122 and 227 of RDP.

The *economic factors* are related to the development of the forest-energy chain and on the market of the wood products from high quality forest species present in the examined area. These factors are represented by market trends for fossil fuels: for US Geological Survey the estimated oil reserves are equal to 3003 Gbo, while the yearly requirements are increasing with a rate of 2.5%. On the basis of these parameters Energy Information Administration U.S. estimated that the world production of oil will reach its peak within 2037 (AA.VV, 2001). Widening in the spreading of centralized plants using biomasses: a progressive substitution of centralized plants with single heating plants using wood fuel and by the introduction of centralized plants using wood biomasses (+91% in 15 years) has occurred (ENEA, 2014). Production costs of the energy: it is possible to highlight the presence of high convenience margins in the use of

natural fuels. If the unit cost of kwh produced with wood chips is made equal to 1, we can then notice that: the kwh produced with diesel is 3,1 times greater, the kwh produced with methane is 2,01 times greater, and the kwh produced with LPG is 1,34 times greater (Lazard, 2014[2]).

The social factor related to Demographic and housing structure: on the basis of the data from ISTAT[3], in the short period the main business target is represented by the 303 houses that rely on diesel and LPG fed centralized plants. 1.652 diesel and LPG fed autonomous plants will be added to the houses in the medium period. Several manufacturing companies and several not registered service companies must be added to these structures (the public buildings).

After an analysis of *technical aspects* for the forest-wood-energy chain (WEC) is possible to underline that WEC would enable the production and use of both the energetic products of the forest and the obtainable timber assortments from the sporadic forest species. Among the examined enterprises, 20% show a very wide and different endowment of machineries for the forest harvesting. Those are farms that use the machineries also for the agricultural activities. Those machineries should be coupled with wood chippers, and they should be chosen in relation to the typology of district heating plants created in the area. In the case of Valtiberina, it is possible to plan heating plants relying on both moving and fixed grid boilers, in relation to the size of the residential nucleus. The moving grid boilers, which have a size greater than 1 Mwt[4], have the advantage of being able of burning wood chips with humidity up to 50%. The use of plug and play heating plants (that are modular plants) is interesting in the case of very small residential nucleus: they are realized in a hook lift shelter made by a technical room with heating system and a nearby silos for the storage of wood chips or pellets.

4.1.2 Internal factors – economic and social

The economic factors are related to production costs and of the economic sustainability of the chains such as chipping production costs (for the wood chips are about 50-80 Euros per ton - humidity of 45%). Another factor is represented by compatibility of the wood chips prices with the

[2] Available on line at http://www.lazard.com/PDF/Levelized%20Cost%20of%20Energy%20-%20Version%208.0.pdf [last access February 3, 2015]

[3] National Institute of Statistics

[4] Thermal megawatt hour.

efficiency of the investments for heating district plants in order to guarantee the economic sustainability of the chain: the return periods are between 5 and 6 years; the breakeven point price of wood chips for district heating plants ranges between 156 and 187 Euros (Fagarazzi et al., 2009). The productions of forest residues from areas with a positive stumpage price (27.000 ha) are almost 20.000 tons per year (Fagarazzi et *al*. 2009). Another factor is represented by the quality of forest resources: the quality is mainly related to the sporadic species and a silvicultural technique called "forestry of tree" with the aim of obtaining from a hard wood forest crop a few number of large-size trees[5]. In the study area, we hypothesize the mixed cultivation of coppice and sporadic trees, where groups of sporadic trees will be managed as high forest inside the coppice. A rotation of one hundred years (for high forest fraction) can be considered. Furthermore, we can also consider four rotation cycles of the coppice fraction, with a potential production of about 800 quintals/ha (q/ha) every 25 years, corresponding to an average value of about 2.500-4.000 €/ha. Finally, a number of target trees (high quality sporadic species) of about 10-15 trees/ha which will generate, at the end of the one hundred period, 10-15 cubic meter of assortments, for a total value of 3.000-15.000 €/ha can also be measured. The total value of the production from sporadic species, in the study area, at the end of the cycle (100 years), could range between 90 and 450 millions of euro.

The social factors are mainly related to workers involved wood harvesting enterprise: a survey on several wood harvesting enterprise of the study area has been carried out. The results of the survey highlighted the following situation: the workers in the sector are mainly represented by unskilled workers (45,7%). The management of the company is mainly part-time (39,1% of the interviewed). The entrepreneurial scenario resulting from the survey is then characterized by non-professional harvesting enterprises, which main activity is not linked to the forest productive sector. All the companies interviewed are interested in the development of the energetic sector, both in terms of selling wood chips and in terms of selling heating.

4.2 SWOT-AHP analysis

[5] The technique most commonly used is girdling. However, it is necessary that the frequency of the interventions is maintained between 6-8 years, while the coppice rotation period is generally 24-30 years.

Since the application aims at detecting the strategic actions that the Public administration could bring about in order to favour the development of the biomass-energy chain and the production from the sporadic forest species, in the long term. A participatory analytical approach (that is a dynamic SWOT model) has been thus developed. This approach is able to evaluate the effects of the strategic actions suggested at the present moment and in the medium term. For this reason, three SWOT analyses in series have been developed with respect to three different scenarios: the present, the medium term and the future ones; In order to define the "relevance" that the weaknesses/strengths and opportunities/threats play in conditioning the examined strategic factor an AHP, for each scenario. In the specific case, the application has been carried out thanks to the collaboration of the local stakeholders (local administrators, forest enterprises' owners, farmers and experts). The latter collaborated to achieve the pairwise comparison matrixes used for the identification of the ranking in which the characterizing components of each factor of the SWOT analysis were included; i. e. strengths/weaknesses and opportunities/threats[6].

4.2.1 SWOT-AHP: present situation

The four dimensions of the SWOT, referring to: the present conditions of the enterprises' structures, of the present typology of the forest standings and of the present market situation of the wood products (sales of firewood in the local market and no production of high quality assortments), have been examined. In order to define the relevance that each factor plays in conditioning the strategic dynamics of the sector, two different AHP analyses have been carried out, in relation to the External or Internal factors of the examined market. Opportunities/threats were first evaluated followed by the strengths/weaknesses of the chains (Fig. 2, 3). The consistency indexes of the matrices (CI) always have values equal or lower than 0,1, which means that the opinions expressed can be considered satisfactory and coherent (Saaty, 1980).

Figure 2 Results for SWOT AHP PRESENT TIME Strengths/Weaknesses

[6]Since the pairwise comparison matrices are based on a rational preference scale, the overall judgment has been calculated using the geometric mean (Saaty, 1980).

Figure 3 Results for SWOT AHP PRESENT TIME Opportunities/Threats

4.2.2 SWOT-AHP medium-term

In order to elaborate the medium and long term evaluations, it was necessary to simulate the stakeholders in the implementation of the action provided by different national and communitarian laws (RDP, etc.), that are: incentives for the production of wood chips and energetic services, improvement of the forest with forest regulation, improvement of the forest standings with high quality broadleaves, improvement of the forest road system, education and updating of the forest workers, to favour the installation of wood chips heating plants and to favour the acquisition of technologies for the development of the biomass-energy chain. In this case, the factors modified themselves, as follows (figures 4, and 5):

Figure 4 Results for SWOT AHP MEDIUM TERM Opportunities/Threats

Figure 5 Results for SWOT AHP MEDIUM TERM Strengths/Weaknesses

4.2.3 SWOT-AHP: Long-Term

In this case, the long-term effects deriving from the regulative actions and from RDP have been simulated. The effects on the four dimensions of the SWOT modified themselves, considering that the enterprises' structures should have moved towards a diversified production (high quality lumbers, energetic products and services, including co-generation), with the presence of forest crops mainly made of hardwood high forests of high landscape and technological value.

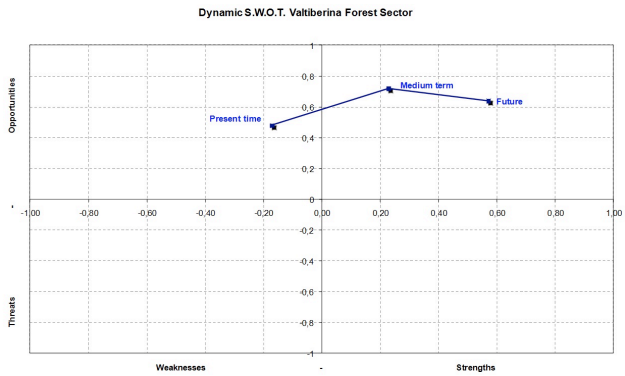
Figure 6 Results for SWOT AHP LONG TERM Strengths/Weaknesses

Figure 7 Results for SWOT AHP LONG TERM Opportunities/Threat

4.3 Knowledge Map development

On the basis of the results obtained with the dynamic SWOT-AHP it was possible to create the knowledge map representative of the feasible development of the sector. The coordinates of each point in the knowledge map are represented as difference between the value of AHP value of opportunity and threat, and strengths and weaknesses. The map allows the visual evaluation of the strengths and weaknesses and of the opportunities and threats of our project for the development of the biomass-energy chain and the production from the sporadic forest species. Through the map, in fact, it is possible to have a clear perception of the results deriving from the previous analyses and to foresee the dynamics of the sector in the future.

Figure 8: Knowledge Map development of the Valtiberina forest sector



In order to develop the map, the data obtained from SWOT-AHP were used. The coordinates of the points (present time, medium-term and long-term) are calculated as a difference between the absolute value taken by the strength factor and by the weakness factor, as well as the difference between the opportunity and threat factors. In this specific case, on the basis of the results taken by the factors it is possible to clearly identify the position of each scenario: present time, medium-term and future. This is possible only thanks to the implementation of the hierarchical analysis, which allowed the quantification of the "relevance" that the strength/weakness factors and opportunity/threat ones play in conditioning the examined strategic factor.

5. Conclusions

This study examined an analytical methodology largely widespread both in the analysis of territorial scenarios and in the evaluation of plans and programmes, i.e. The SWOT analysis. It tried to integrate and innovate through its combination with an Analytic Hierarchy Process (AHP) AHP considers the problem of *ranking* the variables, by lining them up in an importance or preference order, on the basis of quantitative evaluations (Saaty, 1980). The integrated application of a SWOT evaluation with an AHP and, afterwards, the development of a knowledge map, led to the definition of extremely efficacious strategic analyses. This was also enhanced by undertaking a participatory approach in which the local stakeholders collaborated in the illustration of the effects and of the dynamics determined by the political-strategic actions in force. In particular, it was possible for the local administrators to set the action in relation to the priorities detected by the stakeholders, trying to maximize the effect of these structural interventions. Thus the application leaves out of consideration the traditional SWOT model, which is simply a banal listing of the variables, in its more traditional shape. In this case the formalization through a dynamic model, able to quantify the relevance of each component, gives to the final beneficiaries an exhaustive picture of the real relevance taken by all the examined factors, and favouring a better measurement of the programmed action on the territory. In addition, the participatory approach, typical of all the applications based on AHP analysis, favours even more the awareness on the evaluated issues. As for the strategies highlighted with the analytical process, it is possible to point out that in order to promote the development of the forest sector in

Valtiberina it is necessary to favour, in the short-term, the production diversification, by supporting the production of both wood chips for energetic use and energetic services (selling of heat). Moreover, it is essential to educate and update the forest workers and to favour the spreading of new technologies in the wood harvesting enterprises. For this purpose, actions that are strictly linked to the promotion of the demand for new products (wood chips) have to be added in order to favour the installation of biomass heating plants. In the medium-term, it is then necessary to improve the forest component through interventions for the high forest converting stands and the improvements of the forest crops with high quality hardwood (European maple, linden, ash tree, yew).

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