REGENERATION CAPABILITY AND ECONOMIC LOSSES AFTER FIRE IN MEDITERRANEAN FORESTS - LEBANON

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ABSTRACT

The impact of forest fire on three Mediterranean forest types: Pinus pinea, Pinus halepensis/brutia and broadleaved was assessed through three indicators: regeneration capability, wood and Non Wood Forest Product (NWFP) losses. In every forest type, five plots of burnt forest through a sequence of 5 years interval, from 1 to 20 years repeated 4 times, were investigated to follow the plant canopy restoration capability. Another 10 healthy non burnt plots were randomly chosen in each forest type for wood quantity estimations.

The burnt broadleaved trees regenerate immediately through dormant buds located on stems or on roots. The P. brutia has always shown abundant seed regeneration, while the P. pinea regeneration has taken place only in burnt stands whose cones were not collected previously.

The forest understorey canopy regeneration has followed the same plant species that preexist before the fire. The plant composition is related mainly to the "series of vegetation" associated to the soil mother rock, rather than any other abiotic factor. Their density is negatively correlated with the altitudinal zonality. In addition, the germination of opportunistic plant species such as Inula viscosa, as well as the recolonization process of the thorny plants, such as Calycotome villosa, Poterium spinosum Ononis spinosa and Carlina involucrata, was common and dominant in all burnt forest types. With time, some structural changes have taken place according to the trees layer cover (dominant climax): the older is the forest, the more is denser its tree layer and the less the soil is covered by shrubs and herbs. Soil erosion can thus be more accelerated in aged non managed and neglected forests.

The Pinus pinea forest is the most affected by fires. The economic losses are estimated to reach 114330 US $/ha. As for the P. brutia and broadleaved forests, the wood losses were estimated at 21700 US$ and 5812 US$/ ha, respectively. These losses can be diminished if the dry wood that stood upright after the fire occurrence is adequately exploited.

Keywords: forest fire impact, restoration capability, erosion intensity, wood losses

INTRODUCTION

Forest fire prone areas in Lebanon are usually near urban complexes and below an altitude of 1200 m. a.s.l. (Masri *et al*., 2003). The areas range essentially between two

Mediterranean bioclimatic zones: the thermo Mediterranean (0-500 m) and the Meso-Mediterranean (500- 1000 m). They encompass 3 main forest types: the broadleaved forest (mainly *Quercus spp*.), the *P. pinea* forest and the *P. brutia* pine forest (Abi- Saleh 1982; Abi-Saleh and Safi 1988). Other forest types such as *Cedrus libani, Juniperus excelsa* and *Abies cilicia* situated in the supra- to Oro- Mediterranean bioclimatic zones are rarely affected by fire.

The fires usually occur at the end of summer and followed a few weeks later by heavy rain showers, which cause severe soil erosion. This led, along with land mismanagement, to the reduction in the forest cover at more than 35 percent the last 40 years (Masri *et al*., 2002). In spite of that, no forest fire impact assessment has been undertaken till now.

Hundreds of forest fires are occurring annually. A total number of 1413 forest fire events took place in 1997 alone. Between 1998 and 2000 about 35 km^2 of forest were affected (cited by Faour, 2005). Unfortunately, due to some extremism in conservation concepts, forest exploitation (except pruning and pine cone gathering) was totally forbidden during the last two decades by a ministerial decree. Consequently, the neglect has playing an essential role in forest fire occurrence. To overcome this situation, a new ministerial decree allowing controlled forest exploitation was recently issued (Decree no 277/1).

The natural or biological resources losses are usually assessed differently, according to the extracted benefits. Thomas (1999) indicated two main methods for evaluation of natural resources: 1) the direct value that can be derived from their direct use by consumption or production, (2) The indirect value which results from their indirect economic importance for future genetic amelioration and/or for ecological services. At present, there are still no methods, or scientific procedures, to approximate the actual indirect use value. Accordingly, one should use both quantitative and qualitative methodologies to pursue over time the losses of natural resources caused by forest fires and their impacts on ecosystem.

The purpose of this study is to assess the impact of forest fire over time in three Mediterranean forests through three indicators: regeneration/restoration capability, wood losses and Non Wood Forest Product (NWFP) losses. By assessing changes occurring in these main Lebanese forest types, the stakeholders (landowners, policymakers, administrative organizations, NGO's, *etc*….) will be more conscious of the direct and indirect damages and, consequently, can make more accurate judgments of the time and work needed for compensation and restoration.

METHODS

The study area is in Central Lebanon belonging to the bio-ecological Mediterranean ensemble. It extends from the riverbed of Awali in the south to El-Kalb River north of Beirut City and from the shoreline until the contour line of 1300 m. a.s.l. of the Mount Lebanon chain. It has a total surface of 1574 km^2, from which 381 km^2 are dense and sparse forests distributed between broadleaved (74 %) and coniferous (26 %) species. (Extracted from CNRS *et al*., 2002).

Taking into consideration the bioclimatic zones classification and the forest phyto-sociological associations (Abi-Saleh & Safi, 1988; PNUE – MoA, 1996), a systematic sampling design was adopted in two Mediterranean biozones prone to forest fire. They are: the Thermo and the Eu (or Meso) zones. Plots were selected in three forest biotopes which are: 1) the broadleaved forest biotope composed mainly of *Quercus Spp.* 2) the *Pinus pinea* association growing on the Lower Cretaceous sandy formation and 3) The *Pinus halepensis* or *P. brutia* association expanded on calcareous and soft marly soils.

Forest and tree inventory data are collected exclusively within the limits of plots having a quadratic surface of 50 m by 50 m. From the plot center, two perpendicular tracts of 50m x 10m, oriented south – north and east – west are drawn to be used in forest trees regeneration assessment, whereas the plot central area of 100 m^2 was considered as sufficient sampling area for shrubs and herbaceous species (Poisonnet *et al*., 1982; Khater *et al*., 2003). The plot co-ordinates are taken by GPS (Global Positioning System).

To follow the impact of fire on the forest regeneration capability over time, burnt plots had to be chosen in each forest type with a sequence of 5 years interval, from 1 to 20 years repeated 4 times. The total number of studied sites has to be 60 (3 forest types x 5 times interval x 4 repetitions). Nevertheless, this plot number is not sufficient for wood losses assessment which needs knowing the average weight of wood that the forest has had before burning. For this reason, another 10 plots were randomly chosen in each forest type for wood quantity estimations.

In each plot, species were identified directly using illustrated books (Mouterde, 1966; Tohmé & Tohmé, 2002; AFDC, 2005) and subsequently verified in the herbarium recently founded by Tohmé & Tohmé at the National Council for Scientific Research. The assessed indicators related to the forest fire impact are: 1) the regeneration capability of burnt plant species; 2) the losses of wood and; 3) the losses of Non Wood Forest Product. The regeneration capability was assessed through counting the number of seedlings emerging after fire, as well as, the qualitative observation of the spontaneous vegetation dynamics and restoration prospects using the 5 scale Braun – Blanquet methodology. The calculation of woody product was made by counting the trees number and measuring their height and trunk diameter according to Huber's formula: $V= \pi/4 \times D^2_m \times L$ (Bérard, 1996), where V is the wood's weight, D_m is the surface of the cutting at breast height and L is the height of the trunk. The calculation of NWFP was restricted to the edible pine nut losses during a time span of 25 years, the estimated duration necessary for full-fledge tree fructification.

RESULTS AND DISCUSSION

Regeneration capability after forest fire

During the investigation, all encountered regenerated plant species from seeds or from dormant buds were recorded. The interest was in common rehabilitated species found in more than two sampling burnt sites, rather than in occasional taxa. For this reason, 44 species name of the 118 registered plants are mentioned

Restoration capability of the *P. pinea* forest

Despite the sandy soil tolerance for *P. pinea* seed germination, new seedlings were not encountered in the majority of investigated sites. This is due to the common sylviculture practice in Lebanon where the stone pine forests are exploited by annual collection of cones. For this reason, only the neglected (non collected) pine stands have the ability for spontaneous regeneration after fire.

In the burnt *P. pinea* forest type, the broadleaved tree species like *Quercus calliprinos, Pistacia palestina, Ceratonia siliqua* and *Crataegus monogyna,* were rarely encountered. All these trees are of calcicole character do not tolerate soils derived from the

Lower Cretaceous sandstone formation. Only a few numbers of *Quercus infectoria* and *Arbutus unedo* trees specimens have been observed.

As for the lower plant canopy regeneration, 4 shrubs species are widespread. They are *Cistus salviifolius, Lavandula stoechas, Myrtus communis* and later on the *Erica manipuliflora.* Two other plant species can also be cited as typical but less encountered. They are *Cytisus syriacus* and *Halimium umbellatum syriacum*. All these plants represent an affinity for the non calcareous sandy soils on which the ***P. pinea*** forest type prospers.

On the other hand, the wide spreading of the thorny plants represented mainly by *Calycotome villosa, Poterium spinosum* and *Carlina involucrata* is obvious in all burnt stone pine forests. Along with *Inula viscosa,* and some herbaceous plants of *Graminacea* and *Fabaceae* family, thorny plants are hardly competing with the shrubs previously cited, to form altogether the lower plant canopy of the stone pine forest after fire.

To pursue the influence of topographic parameters on the plant recovery speed after fire, the *Lavandula stoechas* was chosen as a typical test plant canopy of the ***P. pinea*** forest type. Plants were taken from sites which were burnt four years ago situated on two northern - humid and southern - dry exposures. In the thermo-Mediterranean site, the plant weight has an average of 180 g on the northern exposure compared to 140 g. on the southern one. When moving from this site through the Eu-Mediterranean to supra-Mediterranean biozones, the *Lavandula stoechas* plant became shorter in height (from 120 cm to 35 cm). Its average weight decreased from 180 g to 92.2 g to 30.1 g respectively. Consequently, with increasing altitude, plant growth goes slower due to the cold weather. The denser the plant cover, the more the soil is protected against soil erosion. The burnt forests situated on higher altitudes and southern exposures are more prone to soil erosion than those situated on lower altitudes with northern exposures.

Restoration capability of broadleaved and *Pinus brutia* forests

The mixed forests encompass several broadleaved and coniferous tree species tolerating well drained soils with different ratios of calcium carbonate content. Their restoration can be defined as the process of its recovery by the pre-existing plant species.

In all broadleaved Lebanese forests, a combustible layer of thick litter has accumulated during the last two decades due to the official position policy, which forbids all kind of forest exploitation. The thicker the litter is, the likelier it is to have a higher intensity combustion which induces a high probability for injury or death of the underground meristematic tissues and roots (Wenger, 1984). Fire duration of 60 seconds over 60^o C is sufficient to entail the entire cells' death (Wright & Bailey, 1982). Nevertheless, in all inventoried burnt broadleaved forests, the trees are vigorously resprouted. The prevailing existence of the ***Q. calliprinos,*** side by side with *Pistacia palestina, **Q.** infectoria* and *Crataegus monogyna* is noticed.

In contrast, the germination of the *Inula viscose,* an opportunistic species, as well as the recolonization process of the thorny plants, such as *Calycotome villosa, Poterium spinosum Ononis spinosa* and *Carlina involucrate,* is dominant. It overcomes other shrub species regenerated from seeds such as *Cistus creticus* or from their extensive rhizomatous system, like *Spartium junceum, Salvia fructicosa* and *Osyris alba*. The herbaceous cover is composed mainly from different *Gramenaceae* species. The abundant existence of *Cyclamen persicum*, *Daucus carota* and *stachys spp*. mainly *stachys distans* is observed.

It is worth mentioning some particularity of the plant recovery of the burnt *P. brutia* stand. Besides the wide spreading of the *Calycotome villosa* and *Poterium spinosum,* some specific plant tolerating the marly soil, such as *Thymus syriacus, Pistacia lentiscus, Salvia triloba* and *Hypericum thymifolium,* has constituted the lower plant canopy of this forest type extended mainly in the thermo Mediterranean bioclimatic zone.

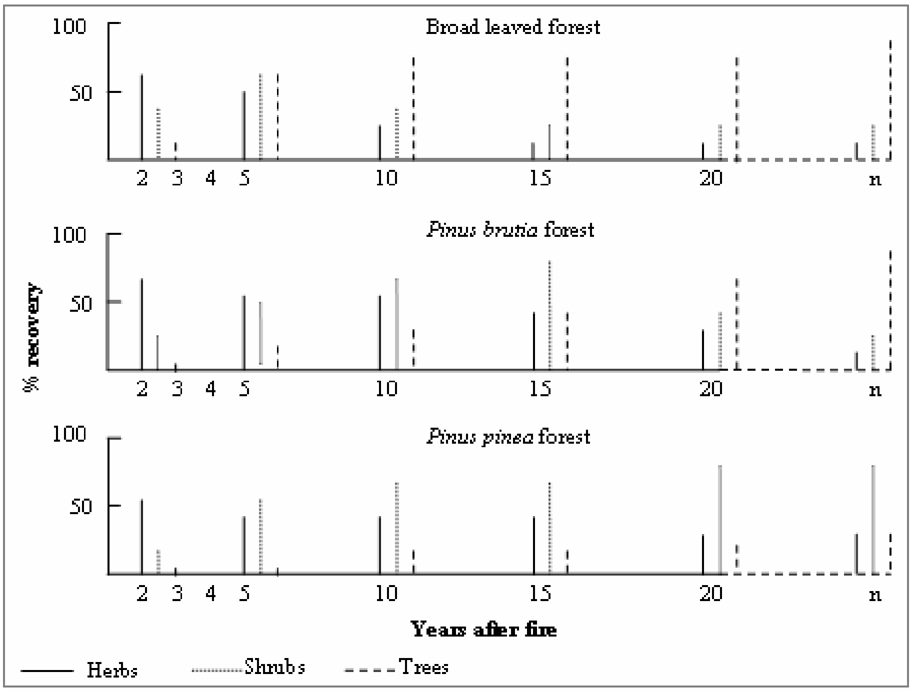

Figure 1. Development of the green cover after forest fire.

The above described plant cover composition of the burnt forests would still be stable during the 5 years after fire. The herbaceous and shrub recolonization improves the water infiltration (Bou Kheir *et al*., 2001) hence it reduces soil erosion which becomes less intense than it was before the fire occurrence (Garcia-Ruiz *et al*., 1996). Later on, some structural changes can take place according to the trees layer cover (dominant climax): the older is the forest, the more its tree layer is denser and the less the soil is covered by shrubs and herbs. Soil erosion can thus be more accelerated in aged non managed and neglected forests. The general tendency of the plant coverage development during 20 years after fire and consequently the potential erosion intensity in the different forest types is illustrated in Figure 1. The common tendency of land cover behaviour can be described as follows:

1) Immediately after forest fire, the degraded sites of all forest types are partially covered by an herbaceous vegetation layer with sporadic existence of different shrubs and tree species depending on their initial existence. At this early stage, the soil texture is deeply destroyed to a finer texture more susceptible to erosion (Ulery & Graham, 1993; Armson, 1977).

2) During the next 5 years, the overall green cover increases with an accelerating dominance of the shrubs layer at the expense of the herbaceous one. The broadleaved species constitute a well-developed climax, whereas the coniferous are sparse and less dense.

3) Ten years after fire occurrence, the broadleaved forest, with prevailing mixed tree layer dominance, can be seen as a mature stand. As for the *Pinus brutia* forest, a homogeneous coniferous tree layer of 2-3 m in height is hardly competing with a dense shrub layer. Until this time, very few *P. pinea* plantlets are observed, except the rare cases where the cones of the burnt forest was previously not collected or the burnt stand was replanted.

4) Later on, both the mature broadleaved and the *P. brutia* forest types have manifested a prevailing dominance of their tree layer accompanied by deep degradation of their herbaceous and shrub coverage. In these quasi denuded soils, erosion process again reappears unlike the case of the *P. pinea* stand, where the sparse trees cover is allowing a shrub cover dominance playing a protective role.

Economic losses after forest fire

The dryness usually prevailing in late summer is responsible for transforming the lower plant canopy of the Mediterranean forest into an ideal combustible. In these conditions, the fire intensity depends on the forest's type, age, and trees density.

To determine the lost wood quantities, two calculation steps are taken: 1) the wood quantities directly burnt during the fire and; 2) the assumed lost quantity of wood related to forest growth delay caused by fire. These quantities are transformed into their equivalence in cash money.

Economic losses estimation of the burnt *P. pinea* forest

In Lebanon, *P. pinea* forest is usually managed like any other fruit trees plantation. A sufficient space between trees is usually left to allow better growth conditions. Trees are pruned once every 4-5 years for better cone fructification, cones are annually collected, shrubs and trees of the lower forest climax are periodically logged or removed by controlled fire. In these conditions, the crown of the mature tree is highly distant from the ground and therefore, can be protected from fire when it occurs. After fire the mature trees having a thick bark and tall height have had temporarily affected. But immediately after winter rainy season, their crown regains its greenness and the tree has survived. It seems that the cambial resistance of the coniferous species, which is proportional to the square bark thickness (Martin, 1963), is playing an essential protective role. In contrast, trees having a thin bark and moderate height of up to 3-4 meters were almost totally damaged, as well as the trees of the neglected unmanaged sites having a trunk diameter less than 30- 35 cm. As a result, the average percent of totally destroyed trees per hectare was 45%.

In addition, another indirect severe impact on the spontaneous regeneration has to be noticed: the *P.pinea* regeneration after fire was rarely encountered. Only once, in a site situated in the thermo Mediterranean bioclimatic zone on sandy formation, the spontaneous regeneration was plenty. This stand was neglected for a long time and has never been managed -which is not the common practice in the Lebanese *P. pinea* forests. For this reason the reforestation activity after fire must be undertaken. Otherwise, the burnt forest would still degrade and the area deserted.

In these burnt sites, the wood losses estimation was not possible due to the fact that thin trunks are totally decomposed, while the thicker ones were logged and removed.

Therefore, the total wood quantity that was lost had to be calculated similarly to that of non burnt, but nearby situated stands. In such a way, an equal number of healthy *P. pinea* stands were inventoried to describe the forest structure. This led to wood volume calculation per trunk diameter thickness as illustrated in Fig. 2.

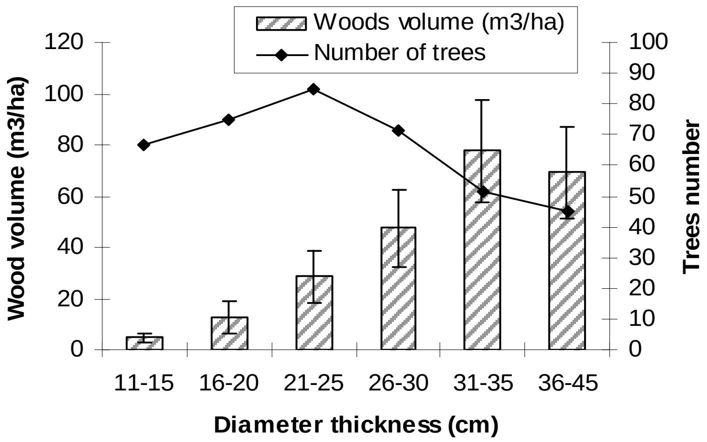

Figure 2. Structure of the *P. pinea* forest.

The average number per hectare is 412 trees which is a high density for a normal pine stone forest dedicated to pine nut exploitation. This fact can be attributed to the young age of Lebanese forests on one hand as well as to its being widespread on sloppy areas tolerating more contiguous trees plantation on the other hand. This situation is ideal for fire acceleration and increased harmful impact.

From Fig. 2 above, 86 % of the trees have a trunk diameter less than 35cm. This category is usually more or less totally destroyed by forest fire and accumulates an average wood volume of 126 m^3/ha. The number can be considered as indicative for wood losses estimation. The *P.pinea* wood of poor quality can be used in carpentry for different purposes. Actually it has a price of US$ 100 per m^3. Therefore the cost is: 126 x 100 = 12600 US$/ha.

If replanted directly after forest fire, the Italian pine forest needs about 25 years to regain its maturity. During this time, a healthy forest can be pruned at least 5 times to enhance its pine nut productivity. In each operation, the volume of the pruned branches is estimated to have about 30 m^3/hectare. This wood is used as energy substitute having a price of US$ 80 for one m^3. Hence, the total price can be estimated as: 30 m^3. x US$ 80 x 5 times = 12000 US$. Hence the total wood losses of a burnt *P. pinea* forest can be estimated as: 12600+12000= 24600 US$/ha.

On the other hand, the average *P. pinea* cone production is estimated at about 10 Kg/tree per year. The time span for regaining fructification capacities is estimated at 25 years. Hence, the post fire losses are calculated as: 10 x 25 = 250 kg per each burnt tree. For the Lebanese forest having a calculated trees density of 412 trees/ha, the cone losses are: 250 x

412 = 103000 Kg/ ha. This quantity represents an economic loss of 89730 US $/ ha. Calculations are based on our previous findings (Masri *et al*., 2004) as well as on the following data adopted by the "Syndicate of pine growers in Lebanon" where: each 100 Kg of cones results in 18 kg of pine seeds, (103000 x 18/100 = 18540 kg/ha); each 100 Kg of seeds results in 22 Kg of edible nuts, (18540 x 22/100 = 4079kg/ha); and the actual price of 1 Kg of edible nuts is equivalent to 22 US $ (4079 x 22 = 89730 US $/ ha).

The total losses in woods and edible pine nut of a burnt *p. pinea* forest are equal to: 24600 +89730 = 114330 US$/ha. This value encompasses the salary of workers involved in wood logging and pine nut extraction.

Economic losses estimation of the burnt *P. brutia* forests

P. brutia is not a planted forest. It is spontaneously regenerated from abundantly disseminated seeds that can be transported by winds. The fallen seeds can get into calcareous soil a suitable condition for their regeneration. This phenomenon was observed during the investigation in all burnt sites despite the rare existence of survived old mother trees.

The *P. brutia* regeneration is not homogeneous in all burnt sites. Burnt sites which were surrounded by forested areas have easer regeneration. Furthermore, there is no correlation between the number of regenerated new plantlets and the survived old trees (R^2=0.0619). In all cases, the investigated sites shown an ability to overcome the degradation caused by forest fire with time: the first years after fire, the number of seedlings was relatively high. It started to decline with time when young trees began competing over light and nutrients.

The *Pinus brutia* forest has the structure illustrated in Fig. 3, where the average trees density is 1487 trees/ha. It is four times denser than that of the *P. pinea* forest. This density allows a rapid and destructive crown fire passage. Furthermore, 88 % of the total trees have a diameter thickness less than 30 cm which is more susceptible to quick combustion. This category accumulates an average wood volume of 217 m^3/ha. Actually this wood has a price of US$ 100 per m^3 making the price of the above volume of 21700 US$/ha.

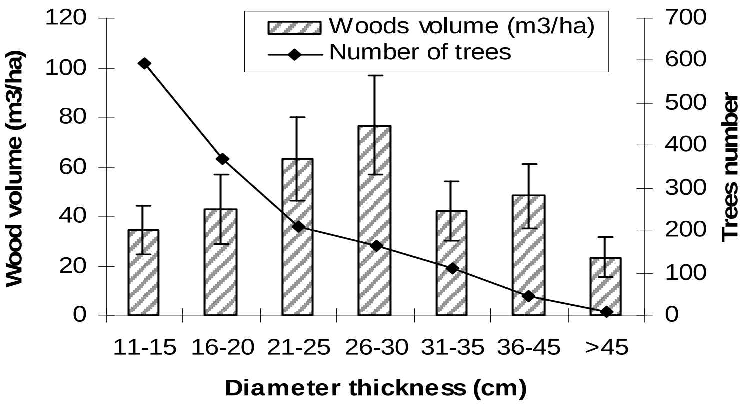

Figure 3. *Pinus brutia* stand structure.

Economic losses estimation of the burnt broadleaved forests

The broadleaved forest is not a homogeneous forest type. It encompasses a large number of trees species. Some of them are widespread such as *Quercus calliprinos* and *Quercus infectoria,* while others like *Cercis siliquastrum, Acer syriacum, Pistacia palestina, Crataegus monogyna* and *Rhamnus spp.* constitute a lower trees climax. These species are exploited for charcoal industry. For this reason, trees and branches having a diameter more than 3 -4 cm are logged periodically (after 10 to 15 years).

The average wood accumulation over time in the investigated burnt broadleaved forests is illustrated in Fig. 4 where it is obvious that trees growth has a linear tendency for the first 15 years after fire. During this period, the accumulated wood reaches an average volume of 46.5 m^3/ha. Some fluctuation of plus/minus 10m^3/ha are observed on northern and southern facing exposure. 20 years after fire, the growth and the wood volume accumulation decelerate. In all cases, these findings are higher than 36 m^3/ha, which is the average wood volume of all broadleaved Lebanese forests cited by the Ministry of Agriculture (MoA, 2005). Such a difference is justified by the fact that the monitored sites in this study area are restricted to dense forests situated in the more humid *senso stricto* Mediterranean bioclimatic zone.

Taking into consideration the actual unit price of the oak wood used as energy substitute and in charcoal industry, that is 125 US$ for one cubic meter, the average wood losses in a burnt broadleaved forest can be calculated as: 46.5 m^3/ha x 125 US$ = 5812.5 US$/ ha.

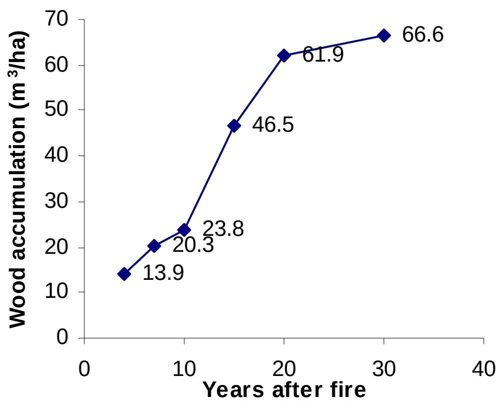

Figure 4. Wood accumulation after fire in broadleaved forests.

CONCLUSION

Under the prevailing *senso stricto* Mediterranean climatic conditions and the local management practices, the forest fire impact assessment on three Lebanese forest types has shown that the forest lower plant canopy regeneration has followed the same plant species that preexist before the fire. Their composition is related mainly to the "series of vegetation" associated to the soil mother rock, rather than any other abiotic factor. Their density is negatively correlated with the altitudinal zonality. The germination of the thorny plants was common and dominant. With time, some structural changes have taken place: the older is the forest, the more is denser its tree layer and the less the soil is covered by shrubs and herbs. Soil erosion can thus be more accelerated in aged non managed and neglected forests.

Since no spontaneous regeneration after fire should be expected in the *Pinus pinea* forest where cones are annually collected, the human intervention aiming at replantation of burnt areas is necessary to minimize the economic losses. This observation should be taken into account by forest managers. In all cases, the calculated economic losses were restricted to direct ones related to wooden resources and edible nuts, while the indirect, long-term losses related to biodiversity and other biological resources need further investigations.

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REFERENCES

Abi-Saleh, B. 1982. Altitudinal zonation of vegetation in Lebanon. *Ecologia Mediterranea*, T. VIII. Fasc. ½ : 355- 364.

Abi-Saleh, B. & Safi, S. 1988. Carte de la végétation du Liban. *Ecologia Mediterranea,* XIV (1/2) : 123- 141.

AFDC - Association for Forest Development & Conservation, 2005. (Supervised by G. Tohmé), *Field guide for common trees and shrubs in Lebanon*. 96 pages.

Armson, K. A. 1977*. Forest soils*. University Toronto, Toronto Press (Ont), 390 pages.

Bérard, J. 1996. (Sous la direction de) *Manuel de foresterie*. Publication de l'Université Laval, Canada, 1428 pages.

Bou Kheir, R., Girard, M.Cl., Khawlie, M. et Abdallah, C. 2001. Erosion hydrique des sols dans les milieux méditerranéens : une revue bibliographique. *Etude et gestion des sol,* 8 (4) : 231-245.

Bou Kheir, R., Shaban, A. and Khawlie, M. 2001. Impact des activités humaines sur l'érosion hydriques des sols dans la région côtière montagneuses du Liban*. J. Secheresse*, 12(3): 157-165.

CNRS, MoA, MoE. 2002. *La carte d'occupation des sols au Liban.* Echelle 1/20000.

Faour, G. 2005. *Towards a sustainable mechanism for forest fires fighting in Lebanon. - Final Report,* 27 pages. Green line association, Beirut, Lebanon.

Garcia-Ruiz, J., Lasanta, T.,Ruiz-Flano, P., Ortiza, L., White, S., Gonzalez, C., Marti, C. 1996. Land use changes and sustainable development in mountain areas: a case study in the Spanish Pyrenees. *Landscape Ecology,* 11(5): 267-277.

Hengst, G.E. and Dawson, J. O. 1994. Bark properties and fire resistance of selected tree species from the central hardwood region of North America. *Can. J. For. Res*., 24(4): 688- 696.

Khater, C., Martin, A. and Maillet, J. 2003. Spontaneous vegetation dynamics and restoration prospects for limestone quarries in Lebanon. *Applied vegetation Science,* 6: 199-204.

Martin, R. E. 1963. Thermal properties of bark. *For. Prod. J.* , 3 : 419-426.

Masri, T., Khawlie, M., Faour, G. 2002. Land cover change over the last 40 years in Lebanon. *Lebanese Science Journal,* 3(2): 17-28.

Masri, T., Khawlie, M., Faour, G. and Awad, M. 2003. Mapping forest fire prone areas in Lebanon. *Proceding of the EARSeL 23 rd Symposium of* "*Remote Sensing in Transition –4th International Workshop on Remote Sensing and GIS Applications to Forest Fire Management,* 6-7 June 2003". P.p 109-113. Edited by Emilio Chuveieco, Pilar Martin and Chris Justice. Ghent University- EARSeL, 233 pages, ISBN: 2-908885-25-5 Belgium.

Masri, T., Darwish, T., Faour, G. and Masri, N. 2004. Land suitability of Lebanese territory for afforestation by *Pinus pinea. Journal of Remote Sensing*, (16): 34-50.

MoA. 2005. *Previous and current trends of forests and forestry in Lebanon* – Lebanon outlook paper to FOWECA- FAO network. Part 1, 28 pages.

Mouterde, P. 1966. *Nouvelle flore du Liban et de la Syrie*. Dar el Machreck, Beirut. 3 Tomes.

PNUE – MoA 1996. Etude de la diversité biologique du Liban. Projet : GF/6105-92-72. *Flore terrestre,* 3, 147 pages.

Poisonnet, P., Austin, M. P., Van der Maarel, E., Romane, F. and Shmidt, W. 1982. Vegetation dynamics in grasslands, heathlands and Mediterranean ligneous formation. *Advances in Vegetation Sciences, Symposium of the International Society for vegetation Sciences,* 4, Montpelier France, September 1980.

Thomas, P. 1999. *The economic valuation of biological diversity*. Eschborn. GTZ publication, 137 pages.

Tohmé, G. & Tohmé, H. 2002. *Thousand and one flowers of Lebanon.* Publications of the Lebanese University, 309 p.

Ulery, A. L and R. C. Graham. 1993. Forest fire effects on soil color and texture. *Soil Sci. Soc. Am. J.,* 55(1): 135-140.

Wenger, K. F. 1984. Fire management in : *Society of American Foresters*, Forestry handbook, 2nd edition. Wiley interscience publ., pp. 235-245.

Wright, H. A. & Bailey, A. W. 1982. *Fire ecology*. United States and Southern Canada, John Wiley & sons, New York, 501 p.