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COMPOSITION

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FIRE'S EFFECTS ON THE ECOSYSTEM: THE *PROMETHEUS* PROJECT APPROACH

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SUMMARY

The fundamental idea of the PROMETHEUS project is the appropriate management of fire as an inherent element of the Mediterranean ecosystems. The PROMETHEUS system is consisted of 6 different modules each one concerning various aspects of pre- and post-fire issues as well as the fire behaviour itself. The aim of the specific contribution is to describe the functional module concerning the fire effects on the vegetation and the ecosystem and final the resilience of the ecosystem.

INTRODUCTION

Fire is long ago considered as an environmental factor shaping the Mediterranean landscapes of the world: Mediterranean Basin and California at the Northern Hemisphere, Chile, S. Africa and SW Australia at the Southern Hemisphere. References to the actions of fire at the Mediterranean type ecosystems are found at numerous sources. However, fire remains an environmental hazard that many times causes serious economic and ecological damages. This fact has led great part of the forest fire research under a technological perspective aiming mainly to fire suppression techniques and fire detection technologies.

However, and despite the fact that important efforts have been made in all EU countries towards the production, the acquisition and the application of high tech facilities and instrumentation in combating fire, fires do occur. On the other hand, efforts of excluding fire from its natural occurrence had also catastrophic effects.

The goal of PROMETHEUS project is to offer an information system friendly to the user based on the understanding that a rational fire management strategy accepts the fact that fire is a structural element of Mediterranean ecosystems. Eftichidis & Varela will present the structure of the whole PROMETHEUS project in detail elsewhere in these Proceedings. The current contribution concerns the analysis of the concepts related to fire effects on the vegetation and the ecosystem as a whole.

PROMETHEUS FIRE MANAGEMENT APPROACH

PROMETHEUS main management objective is not the exclusion of forest fires from the ecosystems, but the control of the occurrence of the rather catastrophic events. It is quite evident that in order to be able to decide which fire event is catastrophic we must have deep and detailed knowledge of the impacts of various fire regimes.

Fire regime is a very complicated issue related both to the characteristics of the fire itself (fire intensity, fire duration) and the history of the site which is subjected to fire (vegetation structure, vegetation composition, fire interval). Fire regime is also related to abiotic factors of the site in reference, that is topography and climate regime.

FIRE EFFECTS KNOWLEDGE ENGINEERING PACKAGE

The various components – modules of the PROMETHEUS system are presented in Figure 1.

PROMETHEUS is a Knowledge Based System (KBS) (see Eftichidis & Varela in the same Proceedings). Estimation and prediction of the potential effects of a given fire regime to the vegetation component of the ecosystem and the ecosystem as a whole are key issues of the

System. For the fulfilment of the aim of this specific job the most important parameters defining fire regime and its implications on its effects on the vegetation and the ecosystem had to be chosen.

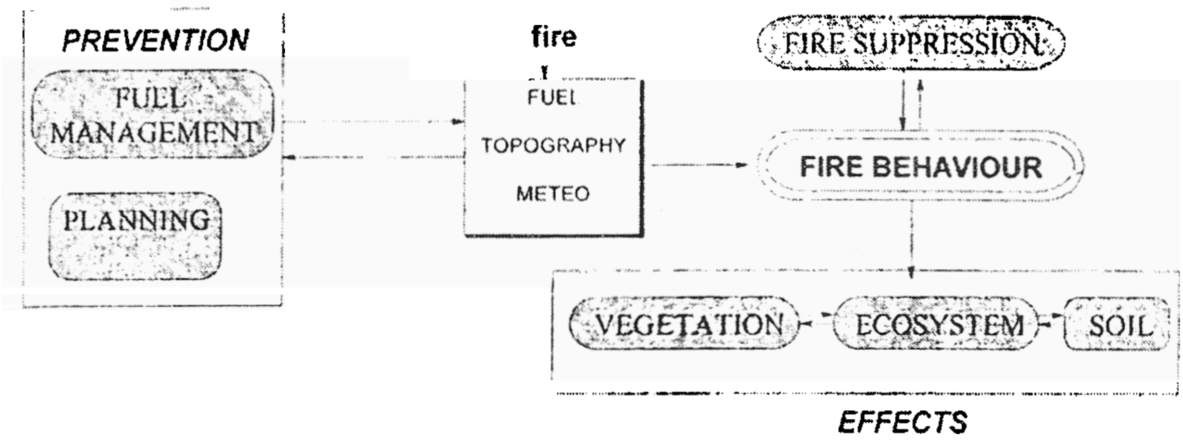


Figure 1. The modules of the PROMETHEUS system

The parameters were initially given a code for reference and they were classified in dependent and independent. Then, they where described in detail by a definition, a sequence of classes, the definition of the classes, the method of estimation and the spatial resolution to which this parameter is valid. This information was inserted in a form unique for all System modules, prepared by the Project Co-ordinator. The set of the forms prepared and filled for each KEP (Knowledge Engineering Package, see Eftichidis& Varela in the same Proceedings) of the System consisted the Data Dictionary of the KEP.

SELECTION OF THE PARAMETERS

The list and the codes of the parameters used in the current KEP are shown in Table 1.

The selection of the parameters was based on the knowledge obtained from the solid ecological work that deals with the effects of fire on the mediterranean ecosystems of the world and of the Mediterranean Basin specifically (Naveh, 1975; Goldammer & Jenkins, 1980; Gill & Groves, 1981; Rundel, 1981; Specht, 1981; Kruger, 1983; Arianoutsou, 1984; Booysen & Tainton, 1984; Moreno & Oechel, 1994; Papavassiliou et al 1994; Bond & Van Wilgen, 1996; Kazanis & Arianoutsou, 1996; Daskalakou & Thanos, 1997; Papavassiliou &

Arianoutsou, 1997; Arianoutsou, 1998 among others). The ecosystem was perceived as a holistic system, which has components strongly interrelated among them. This system is under the influence of the abiotic factors that define its structure and function. As abiotic factors we considered only the climatic factors as these are more directly influence the function of the system at the time intervals we are interested in

Table 1. List of parameters of PROMETHEUS KEP: 'FIRE EFFECTS TO VEGETATION & ECOSYSTEM' – 'REGENERATION AND RESILIENCE'

PARAMETER	*CODE*
BUrned area	BUAR
Burnout TIMe	BTIM
CAnopy Seed Bank	CASB
Fire Line Intensity	FLIN
Fire SeaSoN	FSSN
ManaGement Practice	MGPR
MIcrobial Activity	MIAC
Particle Size Distribution	PSD
Plant Species Composition	PSC
Post-Fire Nutrient Status	PFNS
Potential of INVasion	PINV
PRe-fire soil Nutrient Status	PRNS
PRimary Seedling Recruitment	PRSR
PRe-fire Soil Seed Bank	PRSB
RAINfall Regime	RAIN
RESProuting	RESP
Root REServes	RRES
Secondary Seedling Recruitment	SRSR
Soil Organic Matter	SOM
SOil Seed Bank	SOSB
SUccessional StaGe	SUSG
TEMperature	TEMP
TIME factor	TIME
UNburned Vegetation	UNVE
VEgetation Structure	VEST
REgeneration & ReSilience	RERS

Soil parent rock material was not considered, even if it is an important abiotic factor defining the vegetation type, as it was decided that its influence is sheen as a permanent decisive factor, which doesn't act periodically. In other words it doesn't have the time vector in it. Topography was however included as it was felt that it would define the availability of biotic components (e.g. the seed reserves in the soil). From the biotic components of the ecosystem we have put in the functional diagram only those concerning the primary producers, that is the plants as we decided that these are the key components of the system for our working hypothesis. Apart of the key components of the system, it was decided that key processes relating the plants and the decomposing microorganisms should also be included as they influence the soil fertility. Microbial activity was then included in the scheme. From the parameters consisting the plant community, structure, successional stage, availability of reproductive units –either seeds or seedlings- and resprouting capacity were considered. The set of the parameters and the processes was considered to be under the direct impact of fire intensity, while fire frequency was considered to be as one of the components of post-fire management practices entity.

Examples of the forms prepared for the description and the compilation of the required information for the dependent and independent variables for the current KEP are given in the Annex I.

The parameters and the relationships between them produced Decision Trees (Figure 2), which were then organised in Functional Diagrams (Pressman, 1992) that represent information and data flows (Figure 3). A box represents coded parameters, while a circle represents processes.

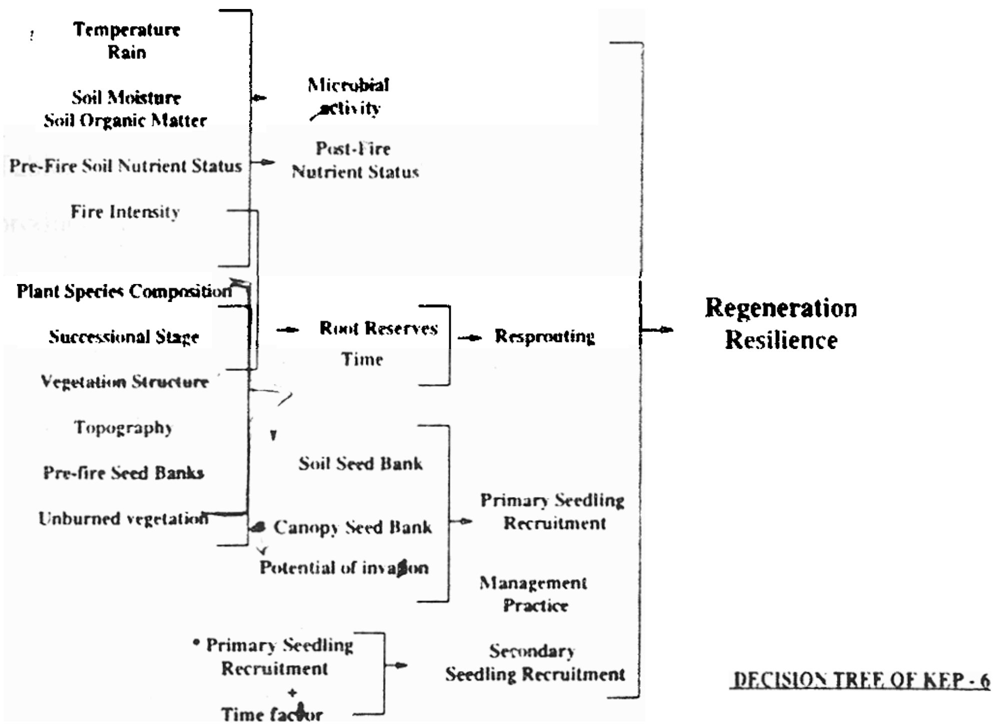
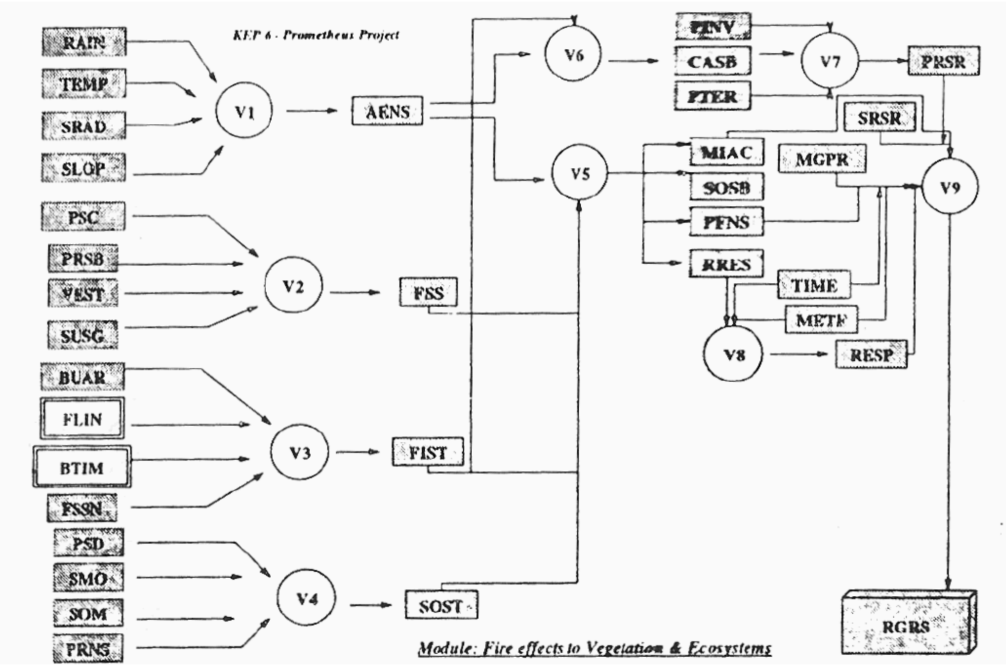


Figure 2. Decision Tree of the KEP "Fire effects to vegetation and ecosystem"

Parameters used in one module (KEP), but produced as outputs of another module are represented in boxes too (second sequence). The final output of the module that can be considered as the objective from the management point of view is shown in a solid box.



It is important to clarify that the parameters selected have seldom -if never- one class only. This means that we had to consider all possible combinations of the classes of the parameters and exclude those that were meaningless. This was a really tough job. Induction Tables were made for this purpose, based on the logic of the IF... THEN statements. The final product of the application of this procedure is a rule-based module, which presents the essential elements on the issue of effects of fire regime to vegetation and the ecosystem.

For example a rule might be:

IF soil organic matter (SMO) is low

AND Fire Intensity (FLIN) is high

AND the patch is in a middle Successional Stage (SUSG)

THEN the post-fire microbial activity (MIAC) will be low

AND the Resilience (RGRS) will be low.

Although this type of rules is qualitative, they do represent valuable ecological information (Salles et al, 1996). The rule-based modelling approach therefore enables us to capture a considerable amount of information that it is usually too broad and detailed and incorporate it into a predictive model. These models also have the advantage that they are simple for the user, the land manager in this case, to understand, to modify and to apply (Legg et al., in press).

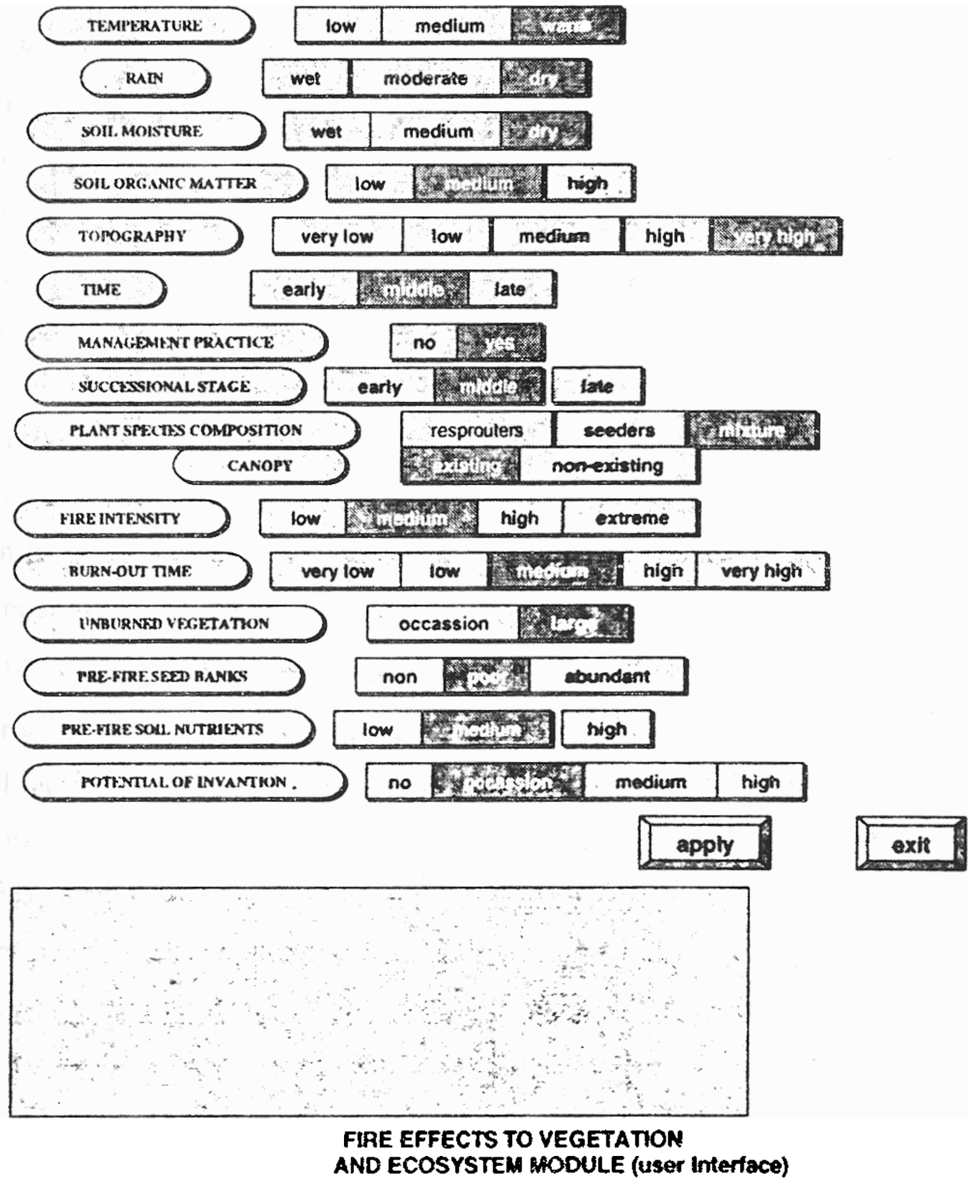


Figure 4. User interface of the PROMETHEUS module on 'Fire effects to vegetation and ecosystem'.

The final product of this work is a module friendly to be used by the manager (Figure 4). Eftichidis and Varela in the same Proceedings describe the operation of this module.

PREDICTING THE ECOLOGICAL EFFECTS OF FIRE

The output of the Module "Fire Effects to Vegetation and Ecosystem' are two key issues "Regeneration and Resilience'. Regeneration is the process, which the plant species put into action after a perturbation –fire in this case- in order to restore their damaged structured. This process in the case of the mediterranean plants species starts either immediately after the perturbation for the repsrouters or after the first autumn rains for the seeders. Resilience is the potential ability of an ecosystem to absorb the perturbation occurred and to recover again. It is evident that Resilience is dependent on the Regeneration -among other parameters of the species- but Regeneration does not imply necessarily that the system is resilient. On the other hand Resilience is very important for fire management, as it is this parameter that will guide the decisions to be taken. Linked to this is the concept of 'acceptable fire'. Acceptable is a fire that can be compensated by the system through its adaptive strategies. Acceptable is a fire after which man should not take any extra management measurements but he can leave the system to cope with it on its own.

From a manager's point of view, it is necessary to know whether and when the burned site will recover, what is the risk of erosion and the subsequent loss of fertility, what is the possibility that a site which had been burned again in the past will be able to recover in case of a repeated fire. On the other hand, an ecologist must be able to provide answers to these questions by analysing the critical and complex property of resilience.

Environmental awareness is steadily increasing nowadays. As a consequence of that more attention is being given to the decisions taken for the management of the systems and for planning the activities. In this context fire can be managed for the benefit of people and the systems themselves, which above all support the people in their lives.

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ANNEX I

A

Name : *Management Practice*
Code : *MGPR*
Type : *Independent*

B*

Definition : It concerns all management practices that may be applied to a given burned site. Usually they refer to timber cutting and removal, grazing and replanting.
The question is whether to treat them overall or one by one.

Classes 1 : (one approach: treat them altogether)
2
No
Yes

Definition of classes : No: obvious
Yes: obvious

Spatial Resolution : Cannot be determined

Change in respect to the fire event:
If they were happening before they would either stop afterwards (no) or temporarily stop (yes).

Classes 2 : 3
a- Timber cutting and removal
b- Grazing
c- Other

Definition of classes : a- obvious
b- obvious
c- obvious

Spatial Resolution : Cannot be defined

C

Procedure :

Module :

Fill only part B of the form

A

Name : *Microbial Activity*
Code : *MIAC*
Type : *Dependent*

B*

Definition : MIAC is the result of the overall output of the vital functions of soil microorganisms. It is defined by the amount of the litter, humus and soil organic matter (which they decompose), by the soil aeration (for their respiration), the soil temperature and moisture (for the performance of their enzymatic reactions) and the soil reaction (pH).

Classes: 3
Low
Medium
High

Definition of classes : Given the fact that MIAC is defined by so many factors it is difficult to give only one combination of them which leads to low or medium or high MIAC.

- In general, MIAC is optimal in spring and autumn, when temperature and soil moisture and in their best combination: not too low not too high, for a given pH and a given organic substratum to be decomposed (Class High).
- The opposite conditions leads to low MIAC for the same pH and organic substratum, while in all the intermediate conditions a medium MIAC is performed.

MIAC is usually measured indirectly, through the activity of an enzyme, mainly that of the dehydrogenase or form the amount of CO_2 released from a soil "spot" in situ. From the literature, we could give the following values for dehydrogenase activity :
low: ‹0.10 mg TPF.g^{-1} of soil, where TPF is the triphenylformazan, which is formed form the transformation of the molecules of 2.3.5 chloro-triphenyltetrazolium added in the soil in the presence of H^+ deriving from the enzyme of the miroorganisms.
medium: 0.10‹x‹0.20 mg TPF.g^{-1} of soil
high: ›0.20 mg TPF.g^{-1} of soil
Please note that these values correspond to alkaline phryganic soil and may be different in other soil types. It is expected though to follow the same trend. As far as it concerns the range of the classes of the microbial activity as it is measured by the CO_2 release values which are close to 1g CO_2 . m^{-2} . 24hr^{-1} are considered as low, while values between 1 - 4 are considered as moderate. Values higher than 4 g CO_2 . m^{-2} . 24hr^{-1} are considered as high.

Spatial Resolution :

Change in respect to the fire event:

C

Procedure :

Module :

* *Fill only part B of the form*

A

Name : *Plant Species Composition*
Code : *PSC*
Type : *Independent*

B*

Definition : PSC refers to plant taxa which exist in a specific site and define its physiognomy and its regeneration mechnisms

Classes: It is difficult to define classes in this parameter. A rough approach would be to check whether the site consists of seeders, resprouters or a mixutre of them. This is closely related to the regeneration capability of the site, its susceptibility to erosion and it reflects its successional stage and fire history.
3 distinct classes ?
resprouters
seeders
mixture

Note: The mature pine forest, with well developed understorey of maquis shrubs is considered as the "climax" situation.

Definition of classes : Resprouters : when a site is repeatedly burned resprouters are the predominant plant group, since the seeders are more sensitive (they need specific period to mature and produce reproductive units).
Seeders : the situation in which the seeders are prevailing in an ecosystem is usually connected with early successional stages, when herbaceous seeding plants are abundant in the sites. This situation refers to normal fire events, when fire occurs every 25-30 years. More frequent events would lead to different situations, with resprouters as the prevailing plants.
Mixture : It is the normal and usual situation of the late successional stages, in normal fire events as well.

Spatial Resolution : Can not be defined

Change in respect to the fire event: See definition of classes.

C

Procedure :

Module :

Fill only part B of the form

A Name : *Regeneration and Resilience*
Code : *RGRS*
Type : *Dependent*

B*

Definition : These two concepts should not be treated as one for the simple reason that eventhough a site is regenerating it might not be resilient. This means that the site might not have the potential to recover again if another disturbance will take place.
So, RG (regeneration) means the process of remaking the structures which have been consumed by a catastrophe, fire in this case.
RS (resilience) means the potential ability of an ecosystem to absorb the perturbation and recover again.
Their main difference is that RG is a biological process, while RS is an ecological potentiality.

Classes: In both concepts 3
Poor
Moderate
Satisfactory

Definition of classes :
Poor : severe degradation of the site has occured.
Moderate : some regeneration is taking place and therefore the ecosystem is slightly overcoming the disturbance - difficulty though exists in deciding whether it can be considered as resilient.
Satisfactory : quick regeneration to a really full extend is taking place - the ecosystem is resilient.

Spatial Resolution : Can not be defined

Change in respect to the fire event:
The RG might be activated and the RS will be prooved as existing or not.

C

Procedure :

Module :

Fill only part B of the form

A

Name : *Secondary Seedling Recruitment*
Code : *SRSR*
Type : *Independent*

B*

Definition : It refers to that cohort of seedlings which appear on the intermediate successional stages and have not originated from the seeds of the soil seed bank, but from the individuals that have initially either resprouted or emerged from the soil or canopy seed banks.

Classes: 2
Low
High

Definition of classes : SRSR does not occur in the early successional stages and for sure not before the recovering plants have reached the age of their reproductive maturity.
Apart of this, some abiotic conditions should occur in order to enable the successful late seed germination. These are mainly related with light availability and quality. Successful secondary seed germination doew not necessarily lead to successful seedling establishemnt, because at this stage other factors, like I nterspecific competition may be more effective.
The values are quite relative since they are dependent on the group of plants of which we are referring, e.g. herbaceous, shrubby or trees. For the first group the values could be much higher than those of the other two groups.
Herbs (legumes) Low : < 100 seedlings/m^2.
Shrubs (rockroses) Low : < 2 seedlings/m^2.

Trees (Pines) very low possibility, with values < 1 seedling . m^{-2}.

Herbs (legumes) High: > 100 seedlings/m^2
Shrubs (rockroses) High : > 2 seedlings. m^{-2}.

Spatial Resolution :

Change in respect to the fire event:

C

Procedure :

Module :

* Fill only part B of the form