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Working Group on Soil Erosion
Task Group 4.1 on
Measures to Combat Soil Erosion

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Thematic Working Group: Soil Erosion

Task 4.1. Measures to combat soil erosion

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Task 4.1. Measures to combat soil erosion

Executive Summary and recommendations

Measures to combat soil erosion cover a wide range of actions to be applied in a wide range of scenarios, according to the diverse driving forces, threats, and target areas. Specific measures vary according to a number of related and non-excluding approaches:

- Source oriented measures and (off-site) impact oriented measures.
- Prevention, mitigation, and restoration measures
- Activity-specific measures: agriculture, livestock management, forestry, transport and construction infrastructures, etc.
- Specific measures depending on local and regional environmental and socio-economic conditions

General principles underlying the proposed measures to combat soil erosion are:

- Production systems should be adapted to land capability and soil suitability.
- Prevention measures should rely on sustainable land use and management; sustainability of land use systems needs to meet both environmental, social and economic conditions.
- Soil protection measures need to be designed in accordance to water management programmes.
- Promotion of protective vegetation cover and/or organic debris (residues, litter) cover.
- Optimisation of soil organic matter levels.
- Promotion of water infiltration.
- The principles of ecological restoration should feed restoration programmes to combat soil erosion.
- An integrated management approach should feed land use planning to prevent coastal erosion, bank erosion, landslides, gullies and debris flows.
- Education and training of land users; increasing awareness of short- and long-term environmental and economical benefits of controlling erosion.

Recommendations

The following table summarises recommendations on measures to combat erosion, according to the activity involved and the stage of degradation driving-forces: active (prevention and mitigation measures) or ceased after degradation (rehabilitation and restoration measures). In addition to these general recommendations, regional- local- and site-specific measures may be applied to deal with specific environmental and/or socio-economic conditions (see report for details).

Synthesis of key measures to combat soil erosion

Land use	Prevention and mitigation measures		
Agriculture	Agricultural practices	Land use planning	Identification of best and marginal agricultural lands; relating major land use to land capability.
			Crop selection and diversification according to soil suitability and soil erosion risk.
			Management of abandoned agricultural lands, particularly in arid and semiarid lands, to avoid further degradation.
		Soil management practices	Improvement of soil properties that positively contribute to reduce erosion, maintaining proper soil organic matter levels.
			Minimising soil tillage, the level depending on soil situation and climate
			Proper timing of tillage practices, avoiding tillage when the soil is too wet or too dry.
			Crop rotations.
			Soil cultivation following contour lines (on the basis of slope and soil type, certain lands may be excluded of this recommendation; e.g. steep slopes)
			Reduction of soil compaction by machines; avoidance of wheel tracks and furrows running up and down the slope.
		Landscape elements	Preservation and maintenance of plant-covered field edges, especially of those which run along the contour. Preservation and maintenance of hedge rows and groves.
			Preservation and maintenance of terraces.
	Rural-landscape engineering to support agricultural practices		Proper size, shape and direction of agricultural fields and farm tracks.
			Rural engineering measures to control runoff (secondary measures to control symptoms): drainage of fields, derivation of inflow from neighbouring areas, derivation of sub-surface water outlets, installation of infiltration areas, obstructing linear depression.
			New constructions of landscape elements: wooded strips, permanent grass strips as buffer areas within fields, contour strips, strips along riverbanks, terraces, etc.
Livestock and grazing management			Establishment of the proper stocking rate, kind of grazing animal, season and duration of grazing for each site. Some useful rules can be established defining limits for the utilisation percentage, the stubble height by the end of the grazing season, and for degradation trend indicators.
			Overgrazed areas should be left aside for some time to recover.
			Integrated management systems involving forestlands, rangelands, agro-pastures, and cultivated lands.
			Grazing and fire can be combined in rangelands and silvopastoral systems provided that a management plan is drawn which specifies when prescribed fire should be used and how the burned areas should be grazed
			Avoidance of practices that cause poaching and high-stocking rates in wet climates/weather
			Access to communal use of public natural pastures in accordance to the application of best management practices

Synthesis of key measures to combat soil erosion (cont.)

Land use	Prevention and mitigation measures	
Forestry	Criteria for afforestation. Forest management	To minimise impacts on soils of site preparation techniques for afforestation: planting holes and contour subsoiling are suitable site preparation techniques; bench terracing and subsoiling along the slope should be avoided.
		Reducing impact on soils of thinning and clearance actions.
		Application of best practices in forest exploitation: planned reduced-impact logging; reduced clear-cutting areas.
		Minimising impact on forest floor materials and soil conservation measures, such as spreading woody debris over skid trials.
		Silvicultural actions aimed at improving stand structure and functioning.
	Fire prevention and post-fire management	Specific programmes for preventing uncontrolled burnings, because it is deeply rooted in the rural population. Co-ordinated actions of persuasion, conciliation and prosecution to modify the human behaviour of the rural population in the use of fire.
		Promote fire prevention through silviculture.
		Controlled burning to reduce fuel load in combination to grazing management.
		Avoidance of savage logging in erosion-prone sites, unless strong soil conservation measures are provided.
Transportation, construction and other sectors	Land use planning	To identify risk areas: areas prone to floods, landslides, and debris flows. Introduction and practise of the Integrated Coastal Zone Management approach.
	Prevention / mitigation	Specific technical approaches and measures available for prevention and mitigation of erosion in transport and construction structures (see report).
		Constructions/solid structures to fix the position of the coastline (revetments, breakwaters, groins etc.).
		Working with natural processes (sand nourishment, stimulate natural protection processes etc.).

Rehabilitation and restoration measures	
Restoration to combat soil erosion	Restoration/reforestation programmes aimed at preserving soil and water and controlling erosion and floods should be designed as ecologically sound, multi-purpose measures, adapted to the new social demands.
	New ecological approach based on (i) restoring ecosystem functioning; (ii) site-specific restoration strategies; (iii) a wide set of species choices; (iii) the introduction of vegetation according to environmental heterogeneity and natural vegetation spatial patterns, with the aim of recover previous landscape processes;
Post-fire soil conservation and restoration	Application of emergency soil-conservation treatments in erosion-prone areas, using on-site slash as mulching materials.
	Promotion of fire resilient plant communities and forest cover restoration.
Rehabilitation of degraded soils	Application of exogenous organic matter (EOM) in accordance with the precautionary principle to maintain soil functions on a sustainable basis. To avoid harmful changes to the soil, exogenous organic matter shall only be applied when there will be no accumulation of contaminants in the soil. Attention must be drawn not only to heavy metal loads, but also to organic pollutants and other environmentally harmful substances.

Task 4.1. Measures to combat soil erosion

1. Introduction

The framework for combating soil erosion is land use planning, according to the principles of land capability and soil suitability, and sustainable land use and management. Hence, there is also a need to determine land vulnerability. Within this framework, actions aimed at enhancing or maintaining soil organic matter levels, water infiltration, and vegetation or plant residue cover specifically address soil erosion.

Most key is educating users to look after the soil. Education and dissemination actions aimed at increasing awareness on the environmental and economic benefits of controlling erosion should be a major part of any programme for implementing control measures. Training and support for changing traditional management is needed.

All actions need to be targeted on particular areas that are vulnerable to erosion. This will be more effective in protecting these areas than a broad brush approach. There are only **limited financial and human capacities**. Therefore it is necessary to use these limited capacities in an efficient way. Activities or measures have to focus on those aspects where problems concerning the health of soils are evident.

The following approaches of combating soil erosion can be distinguished, although a strict subdivision of measures into these classes is not always possible as some measures fit to more than one approach:

Prevention, mitigation and restoration measures

- **Prevention** and **provision** are oriented to the potential risk of the site, even though damages did not yet occur. These measures mainly focuses on proper land and soil management
- **Mitigation** and **defence** actions, which are applied when relevant erosion is currently occurring. In case of severely degraded and eroded soils, mitigation measures may include the abandonment of the exploitation system.
- Once the land is degraded and the spontaneous reversion of degradation processes can not be expected at management time scale, even if most of the erosion driving forces have ceased, ecosystem need to be repaired by **rehabilitation** and **restoration** actions.

Source oriented measures and impact oriented measures[1]

- **Source oriented measures** control the soil erosion process directly at the place where it starts, they aim at reducing kinetic energy of falling drops with a protective vegetation cover, maintaining infiltration capacity and reducing flow velocity of surface runoff. In agricultural lands, these measures include soil management practices leaving great amounts of plant residue at the soil surface or maintaining a permanent or semi-permanent plant cover in perennial crops (conservation agriculture techniques). Other measures

[1] Kainz, 1991. Schutzmaßnahmen gegen Bodenerosion. Berichte über Landwirtschaft, Bodennutzung und Bodenfruchtbarkeit, Band 3, 83-98, Parey

controlling the amount of runoff generated within a field can also be considered as source-oriented, such as contour ploughing (increasing soil surface roughness), and the maintenance of linear landscape elements (decreasing slope length). A correct choice of land use respecting the principles of land capability and soil suitability also belongs to the source-oriented measures, implying the provision of soil erosion damage that did not yet occur, oriented to the potential risks of the site. Sustainable grazing management, sustainable forestry, fire-prevention actions and most restoration actions to combat soil erosion are also source-oriented measures.

- **Impact oriented measures** control the effects of soil erosion as close as possible to its source. Most of these measures aim at reducing the amount of sediment (detached soil material) being transported into surface water bodies (streams and lakes…) and any other area or infrastructure to be protected (housing, roads, nature reserve…). Such measures include grass buffer strips, grassed waterways, earth dams, retention ponds, etc. in agricultural lands; check dams, soil-retaining vegetation barriers, etc. in forest lands and drainage systems in transport infrastructures, among others. However, they also contribute to the prevention of soil erosion downstream, by controlling both velocity and amount of runoff. The more upstream in the catchment such measures are located, the more source-oriented they are, whilst the more downstream, the more impact-oriented.

The above-mentioned approaches are very closely related. Thus, most source-oriented measures are preventive actions and most impact-oriented measures are mitigation or defence actions. In the long-term, prevention and source-oriented actions are the most effective measures in reducing both the risks of on-site-damages as well as risks of off-site-damages.

Specific approaches also depend on land use. The present report analyses erosion control measures according to target activities: agriculture and livestock, forestry, transport and construction infrastructures and others. The context of desertification deserves special mention. Training, monitoring and research actions are also considered.

2. Concrete measures in agriculture (including pasture lands)

2.1. Agricultural Practices to combat soil erosion

This report analyses agricultural practices within the following major topics:

- Land use planning: Location of agricultural land and crop diversification.
- Soil management practices; improvement of erosion reducing soil properties.
- Preservation of the natural landscape elements that contribute to control overland flow and soil erosion.

2.1.1. Land use planning: Location of agricultural land and crop diversification

Land use planning policy should relate major land use to ***general land capability*** and ***relative soil suitability***, for each particular site and socio-economic context, which can be really based on knowledge and information following the traditional land evaluation analysis. Rural planning tools (directives; regional, national and local regulations; etc.) can be used at the various scales concerned.

Agricultural marginal lands used to be a suitable scenario for soil erosion. The relationship between current land use and agricultural capability (potential use) is clearly unbalanced in many European regions. As an example, about 1 million of hectares of rain fed agricultural lands in Andalusia, Spain, should be changed to forestry, grazing or natural lands in order to get a balance between land capability and land use[2]. On the other hand, soil exploitation of best agricultural lands for building purposes should be minimised. Therefore, the first land use decision is the identification of the best and the marginal agricultural lands, and the identification of high-risk soils.

In Northern countries, good land use planning would for instance imply that arable farming of marginal land for cereal production is avoided. These lands can be transformed into grazing land, hay fields, forest lands or can be used for the production of bio-energy, or for Christmas tree plantations.

Within the framework of land consolidation, the different land uses can be redistributed in critical areas in order to reduce potential damages related to soil erosion. For example, this can lead to a corresponding interchange between pasture and arable lands within an area. A critical area is a site with remarkable soil loss and/or overland flow risks that is located nearby a protected area; “nearby“ means areas from which overland flow and erosion material can easily reach a protected subject (or a subject needing protection).

Within the agricultural lands, all soils can be used for almost all crops if sufficient inputs are supplied. However, each soil unit has its own potentialities and limitations (soil suitability), and each crop its biophysical requirements. In order to minimise the socio-economic and environmental costs of such inputs, the second major objective of land use planning is to predict the inherent suitability of a soil unit to support a specific crop or crop rotation for a long period of time[3].

The development and essay of methods and techniques to assess the soil suitability and vulnerability related to land uses are necessary in order to exploit in an environmental friendly way the multifunctionality of soil. The soil key attributes used in land use planning for soil erosion, through the land evaluation analysis, are mainly soil physical/chemical indicators. At present, the soil biological indicators are not used in land evaluation. Site quality indicators of particular relevance to soil erosion mainly relate to soil erodibility, infiltration capacity, and slope conditions (steepness, length, and shape). The distance to an off-site area that is to be protected (e.g. surface water) is also relevant.

2.1.2. Soil management practices

- √ ***Improvement of soil properties*** that positively contribute to reduce erosion risk and develop stable top soils. These measures include: enrichment of organic matter in order to reach the site-typical humus level by adding animal manure or other materials; promotion of an equalised humus balance; support of stable soil aggregates and soil structure by stimulating the biological activity, by liming, by promoting stable humus forms.

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[2] AMA, 1987. Evaluacion ecologica de recursos naturales de Andalucia. Scale 1:400,000. Coordinators: D. de la Rosa and J.M. Moreira. Agencia de Medio Ambiente Pub. Sevilla

[3] De la Rosa D. and Van Diepen C. 2002. Qualitative and quantitative land evaluation. In W. Verheye (ed.) Land use and land cover, Encyclopedia of Life Support System (EOLSS-UNESCO), Eolss Publisher, Oxford. Http://www.eolss.net.

Long-term benefits associated with ***organic farming*** include increased soil organic matter content, greater topsoil depth and moisture retention, which in turns contribute to reduce soil erosion[4]

√ Formulation of a ***conservation tillage system according to site conditions*.**

Soil tillage is carried out to prepare the seedbed to grow crops, to control weeds, and to incorporate manure, fertilisers, pesticides and other amendments. Inappropriate tillage practices accelerate the soil degradation processes, especially soil erosion and compaction. To formulate the tillage type and intensity for each particular soil is a critical point to combat the soil erosion problem in the agricultural lands.

In general terms, tillage systems can range from full width intensive tillage to zero tillage (i.e. conventional tillage, reduced tillage, ploughless tillage, minimum tillage and no-tillage). ***Conservation agriculture*** (CA) includes practices that reduce, change or eliminate tillage and avoid residue burning to maintain enough surface residues through the year, so that the soil is protected from rainfall erosion. Specifically CA includes: direct sowing/ direct drilling/ no-tillage; ridge-till; mulch till/ reduced tillage/ minimum tillage; and cover crops (Annex 1).

A common technique is ***mulching***, e.g. after freezing in winter, catch crops or small-grain cereal form a layer of mulch on the soil surface. In spring the crop can be drilled directly into the mulch and the soil is completely protected till the new crop forms a consistent canopy. In general, leaving stubble uncultivated is preferable to leaving the soil bare.

The conventional repeated tillage system accelerates decomposition of organic matter thus affecting soil physical, chemical and biological attributes of soil quality. On the contrary, with the no-tillage system (direct sowing), several studies[5] show that continuously organic matter increases and soil structure improves, restoring and improving soil quality, crop yields increase, and soil erosion is controlled. However, other studies[6] point out how the level of success in no-tillage system varies with i) crop species, ii) soil type, iii) climatic conditions, and iv) growing season length.

A major concern with CA is the application of herbicides and pesticides. The need of such herbicides is generally assumed to be higher, especially for the most drastic forms of CA, i.e. no till/direct drilling. However, this may be site-specific (e.g. humid environments may suffer more from fungi or slugs than dry areas) and information is scattered and incomplete. In fact, the environmental consequences of CA have not systematically been investigated, and this needs to be done for different forms of CA in different agro-ecological zones. A critical and objective literature review is required, and probably, further research is needed to investigate which forms of CA can be applied in which ago-ecological zones with acceptable environmental impacts (Annex 2).

In order to rationalise the soil tillage practices, a conservation tillage system should be

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[4] Reganold J P, Elliott L.F., Young L.U. (1987) Long-term effects of organic and conventional farming on soil erosion. Nature 330, 370-372.

[5] e.g. Tebrugge F. and During R.A. 1999. Reducing tillage intensity - a review of results from a long-term study in Germany. Soil & Tillage Research 53: 15-28.

[6] e.g. Arshad M.A. 1999. Tillage and soil quality: Tillage practices for sustainable agriculture and environmental quality in different agroecosystems. Soil & Tillage Research 53: 1-2.

formulated for each specific site, giving details on the operation sequence, implement type and intensity.

Timing of tillage practice is as important as tillage intensity. Tillage operations should be avoided when the soil is too wet or too dry. The limits in soil water content can be predicted in terms of soil composition through the use of pedotransfer functions.

For Mediterranean climatic conditions, repeated tillage under dry soil conditions appears to promote topsoil pulverisation and enhance soil erosion. Finely pulverised soils are usually smooth, seal rapidly and have low infiltration rates.

In Western Europe, a lot of the erosion problems are caused by a wet climate particularly in late summer and autumn when most cultivation takes place. Tilling at the wrong time i.e. when the soil is too wet, leads to compaction or soil sealing which prevents water infiltration and increases run-off, which can result in extensive sheet erosion and gullying on all soil types. Any type of cultivation, conventional or otherwise, will result in a degree of compaction if carried out when the conditions are too wet.

Soil cultivation following contour lines. On the basis of slope and soil type, certain lands may be excluded of this recommendation, e.g. steep slopes and in case water is concentrated in natural drainage lines (hollows).

Ploughing along contours should be practised with turning earth in direction against the slope (partial erosion compensation). It is useful when all the other agro-technical measures (drilling, agro-chemistry measures, etc.) are also made following the contours.

√ ***Crop rotations***. The use of crop rotations leads to soil protection by ensuring plant cover as much as possible, which supports the enrichment of humus in the soil through the incorporation of their organic remains. On erodible land, crops that can be considered as low-protection crops should be avoided in a rotation, and should be forbidden in monoculture in case no sufficient erosion control measures have been set. Examples of such crops are maize, other row crops (sunflowers) and root crops (potatoes, sugar beet, endive roots, etc.). On the contrary, a crop rotation on erodible land should include cover crops or catch crops for reducing the loss of soil and nitrogen during winter time; e.g. use cover crops such as rye or mustard in late summer or early autumn. Cover crops should also be grown in perennial crops on steep slopes, particularly in no-tillage systems on soils with low infiltration rates and prone to surface sealing.

√ ***Reduction of soil compaction*** by machines and avoidance of wheel tracks and furrows running up and down the slope.

The increased density of the soil just beneath the depth of tillage (subsoil compaction) is one of the most striking effects of management systems. Tillage and traffic with increasing weight of agricultural machinery cause the subsoil compaction. This problem is especially severe in heavy-textured and poorly drained soils. Sub-soiling, deep ploughing, para-ploughing and numerous other devices have been developed to alleviate the problems created by compaction. The compaction risk or vulnerability of agricultural soils, measured by the pre-compression stress, can be used to give recommendations for site specific farming systems (e.g. implement type, wheel load, and tire inflation pressure). Also, it can allow the agricultural machine industry to develop site-adjusted machines to support the ideas of good farming practices. For more details on measures to prevent soil compaction, we refer to the report on work package 5.

√ Other site- and use-specific measures such as:
- To ***keep waterways on the fields covered*** with stubble and grass or catch crops, at least during most risky periods.
- In Northern Europe countries: to ***avoid autumn ploughing*** of arable land with high and very high erosion risk.
- To drill winter cereals early, without gaps in tramlines.
- To ***avoid fine seedbeds*** that will run together and seal soil surface. Rough seedbeds are more stable.
- Proper ***orientation of crops*** in vineyards and orchards.
- Careful ***irrigation management*** to avoid runoff and erosion. Assessment of crop water needs and control of water droplet size.

2.1.3. Preservation of the (semi-) natural landscape elements

√ Preservation and maintenance of ***plant-covered field edges***, especially of those that run along the contour.

√ Preservation and maintenance of ***hedge rows and groves*** which are able to absorb and infiltrate overland flow respectively to hold up erosion material.

√ Preservation and maintenance of ***terraces*** (in cases, in which they are not more suitable for special land use management or special crops, management or crops should be changed, but terraces should be preserved if possible).

Terraces in the Mediterranean region.
At present, Southern Europe faces crucial problems regarding terraced landscapes due to (i) the extensive abandonment of mountain rural areas and therefore of their soil and water conservation structures and (ii) intensification in modern agriculture that leads to land levelling operations destroying the structure of the terraces.

Four main issues need to be addressed:
1. Conservation of terraces.
2. Restoration of degraded terraced landscapes.
3. Identification of hot spots in Europe where terraces have a special risk for abandonment and related land degradation and erosion problems.
4. Preservation of knowledge about the traditional way of making, repairing and maintenance of terraces. How to stimulate and spread this knowledge? The relation with cultural landscape and national heritage should be highlighted.

The main challenge in the Mediterranean Basin through the history has been, and should be at present, to sustain the fragile and scarce natural resources of water and soil. Since the Roman period, natural and/or man-made terraces throughout the basin have been utilised for water harvesting and soil conservation. These structures were/are part of the indigenous agricultural domains i.e. the agroscapes allocated for particular traditional crops of the Mediterranean such as the olives, vineyards, pistachio, almonds, figs, etc., and grazing for small ruminant such as the goat. Natural Pleistocene terraces were also used as agro-ecosystems. Conservation of these natural and man-made surfaces seeks to secure and/or increase the suitability of the soils overlying calcretes (caliches) and karst limestone for rainfed crops.

The indigenous technical knowledge on how to manage terraces and their crops, which secured the sustainable management of the land in the past, should be taken into account when designing current measures to control soil erosion. This technology comprises a minimal initial tillage and irrigation, so degradation of soil structure as well as leaching of nutrients and loss of limited water resources were prevented.

Measures for terrace conservation may not to be able to cope with the extensive abandonment of mountain rural areas that has experienced the Mediterranean region in the last decades. Therefore, at present and in the next future, a widespread collapse of terraces can be expected. To set priorities for actions, identification of degradation hot spots and sites of particular interest is needed. Specific restoration measures to prevent soil erosion in degraded terraced landscapes should be developed and tested.

2.2. Measures of rural and landscape engineering to support agricultural practices.

2.2.1. Size, shape and direction of agricultural fields, construction of farm tracks

Land use management (tillage, direction of crop rows etc.) along the contour lines can be promoted by a suitable shape of the field and by a respective course of the farm tracks; this should be considered and used in lands at high erosion risk.

In case that land ***levelling*** is needed an ***impact assessment*** should be necessary to look at the impact on erosion, and adequate measures against erosion should be taken

2.2.2. Rural engineering measures to regulate the runoff conditions

These measures are mainly designed to combat the symptoms rather than the causes of soil erosion; accordingly they are secondary measures.

√ ***Drainage of fields****:* Additionally to the measures by which the farmer can improve the infiltration and avoid the formation of overland flow on arable field or grassland, drainage (pipe, mole or slit drainage) can reduce overland flow on the field itself and onto farm roads, tracks, concrete areas and other off-site objects. Control drainage water from fields by maintaining land drains, pipe outlets and ditches; remove sediment deposited in ditches and drains. Avoid unstable system of ditches in erodible terrain.

√ ***Contour ditches on more gentle slopes***, with distance spanning 60 to 100 metres, represent a new system for defining sufficiently large surfaces for machinery. The ditch's depth is set up below the plough sole so that a sub-surface draining action is guaranteed.

√ ***Derivation of subsurface water outlets*** on slopes, which can cause linear erosion forms or mass movements; the derivation of these outflows normally can be made by single incepting drains;

√ ***Derivation of inflow from neighbouring areas***, e. g. from a farm track running above the effected field or from a neighbouring field together with more or less erosion material; if the real cause cannot be eliminated, the derivation normally can be made by a suitable ditch track or by discharging the inflow water in an intake area;

- √ ***Installation of intake areas*** (infiltration areas), e. g. above boundary strips. Infiltration areas can be located on flattened areas at the lower edge of fields (at the end of linear erosion forms, but also at locations where sheet erosion and overland flow are crossing over a wide line), provided that soil and subsoil are sufficiently capable of absorbing at these locations; intake areas may also be installed for runoff derived from subsurface water outlets (see above);

- √ ***Sedimentation ponds*** would positively contribute to the quality of water resources.

  Adding Al or Fe compounds to water flowing into the sedimentation ponds helps to bind P. This measure is cheap (Euro 3,5/ha) and has been applied in some Northern countries. However, there is a risk that Al will appear in free form in lakes with a low pH, which is toxic for the fauna. Therefore, this method should be only applied under strictly controlled situations (e. g. in a water purification plant).

- √ ***Obstructing linear depressions***: in addition to control off-site damages, this measure contributes to the conditioning of critical local relief properties and of prominent ways for overland flow; these linear depressions are exposed to rill and gully erosion and along them runoff and erosion material can be transported for long distances.

2.2.3. New constructions of landscape elements (buffer strips, terraces etc.) and repair or extension of existing ones

Different landscape elements help to reduce the erosion-effective slope length, they support a harmless discharge of runoff and protect surface waters and other parts of the landscape.

- √ ***Wooded strips, hedgerows and groves*** with intensive undergrowth (low-growing vegetation) running along the contour lines. These strips subdivide long slopes, absorb sediments and overland flow. However, it must be prevented that linear erosion and runoff forms (rills and gullies) break through these strips.

- √ ***Permanent grass strips*** as buffer areas within fields; ***contour strips*** (alternating crops, e.g. strips of grains or grass within root crop and maize fields).

- √ ***Strips along river banks***: broad vegetation strips with well developed undergrowth; their role of protection is comparable with that of the aforesaid landscape elements; they shall reduce the input of erosion material and of loaded overland flow into surface waters; but it must be paid attention again that linear forms (rills, gullies) do not break through.

- √ ***Terraces, plant-covered boundary strips***; they subdivide the slope and diminishes the slope length and steepness; new constructions of terraces are however very expensive; Linked bench terracing has been proposed for valuables vineyards on sloping surfaces in the sandy soils of the Asti province (Piedmont, Italy). These terraces follow a zigzag path up and down the slope, allowing continuity between subsequent planes.

- √ ***Integrated biological systems***: by ecological means, the landscape elements mentioned above should be connected with each other in an integrated system.

2.3. Specific measures to combat wind erosion

Most of the above measures have been designed for preventing soil erosion by water. Lowlands and plains are target areas for measures to combat wind erosion. Most vulnerable to wind erosion are texturally light soils (sandy, loamy).

Specific protection measures against wind erosion are:

- Wind breaks, typically consisting of three or five rows of plants along affected fields, planted for example in the order:
    - *low hedge – high hedge – low hedge,*

  or
    - hedge – *low tree – high tree – low tree – hedge*.
- Diminishment of field length in main wind direction (by wind breaks or by strip farming),
- Suitable crop rotation,
- Conservation agriculture,
- Improvement of humus level,
- Maintenance of soil surface roughness,
- Change of land use, if possible, on exceedingly endangered sites (grassland instead of arable land).

2.4. Concrete measures for pastures lands and grazing management

The European Common Agricultural Policy (CAP) determined, by means of premiums, regulatory measures and quotas, some trends in farming systems that increased the risk of soil degradation. Temporary grassland, that exerts beneficial effects on soil, declined, while fodder maize for ensilage increased also under rather unfavourable conditions (e.g. in areas liable to flood, or on slopes). The number of sheep and goats in EU has remarkably increased after a quota system was introduced.

Grazing by domestic or wild herbivores is an ecological factor contributing to ecosystem function, diversity and stability. In central European alpine regions, the recession of the use of high mountains pasture often is a reason for beginning erosion and landslides. Accordingly, maintaining and promotion of high mountains pasture is an important measure against erosion, as long as the management intensity of the pasture is adapted to this sensitive alpine vegetation cover. Grazing however must be rational and adapted to specific conditions of each ecosystem and landscape. This means that the stocking rate should be equivalent to the grazing capacity of a particular site, and the type of grazing animals and the grazing system, namely the season and duration of grazing, should be appropriate for the type of vegetation/rangeland to be grazed; e.g. in the Mediterranean rangelands, it is always recommended to combine grazers and browsers.[7]

The stocking rates may be defined depending on climate conditions; e.g. livestock densities in forage production lands in Spain must comply with the following thresholds:

Annual rainfall < 400 mm: 0.5 Livestock Unit/ha
Annual rainfall 400 – 600 mm: 1 LU/ha
Annual rainfall 600 – 800 mm: 1.5 LU/ha

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[7] Papanastasis, V.P. (2003). Grazing management in the framewok of sustainable management. MEDRAP workshop on Prevention and Mitigation Actions to Combat Desertification. Alicante, June 2003.

Annual rainfall > 800 mm: 2 LU/ha

Grazing and fire can be combined in rangelands and silvo-pastoral systems, provided there is a management plan that specifies when prescribed fire should be used and how the burned areas should be grazed. Overgrazed areas should be left aside for some time to recover before animals are again introduced so that overgrazing effects are mitigated.

Additional measures to control erosion in pasture lands include:

- √ Avoid practices which cause poaching (problems can occur from gateways, high stocking rates in wet weather, etc.).
- √ Avoid overgrazing near or with access to riverbanks. Fencing may be required.
- √ For outdoor pigs: careful site location to minimise erosion risks; take account of location, slope, soil type and rainfall. Site management to maintain grass cover or rotate sites.
- √ To locate supplementary feeding areas away from water courses; regularly move feeding areas.

2.5. Preventive measures in abandoned agricultural lands.

After the abandonment of agricultural land, especially in dry lands, a management programme has to be established in order to prevent further degradation. Since degradation processes depend on the state of the land at the time of abandonment, prevention measures should include land-abandonment accompanying actions aimed at ***maintaining the soil covered*** (e.g. by leaving plant residues on site).

In case of abandoned land in humid and sub-humid regions, the self-regulating development of natural vegetation (grass, weed, bushes, later wood) normally doesn’t need support – except for the first years of abandonment and except for keeping the landscape free of unwanted vegetation developments. However, in central European alpine regions, where the recession of the use of high mountains pasture often is a reason for erosion and landslides, maintaining and promotion of high mountains pasture is an important measure against erosion, as long as the management intensity of the pasture is adapted to this sensitive alpine vegetation cover.

In the case of semi-arid lands, abandonment is usually followed by further degradation, and this is enhanced by the destruction of soil conservation structures (like terraces). Terraced old fields usually concentrate the deeper soils on the hill slopes, therefore they constitute preferential spots for land restoration.

Nowadays, ***maintenance of soil conservation structures*** (dams, terraces) is not a cost-effective measure, unless the socio-economic conditions at the site (e.g. areas of high unemployment) allows the maintenance works, and/or the site is of particular interest for keeping them up, and/or off-site damage risk is very high. In most cases, collapse of these structures will occur. Measures to prevent soil degradation and erosion should be focused on creating ***soil-retaining vegetation barriers*** of deep-rooting and high cover shrubs and trees.

Often, fire-prone ecosystems develop after land abandonment in southern Europe due to fuel accumulation and landscape homogenisation, and this mostly occurs in the vicinity of settlements. These areas should be priorised target areas for fire prevention actions.

There is an urgent need to devise recommendations for the Mediterranean region taking into account its particular environmental conditions. Particular emphasis should be placed on finding feasible land use alternatives to agricultural marginal areas. The CAP measures for ***afforestation of marginal fields*** are promoting the use of a wide range native species. However, careful selection of the suitable species for each site is needed. Studies on the possibilities of utilising native vegetation for conservation and economic return should have high priority in such areas. Control of subsidies through the assessment of the quality of the restoration programme, species selection, and techniques, is recommended.

3. Concrete measures in forestry

Concrete measures in forestry to prevent soil erosion deal with a wide range of conditions, from highly productive systems, where afforestation and reforestation are managed towards wood production, to non exploited systems that mainly contribute to soil and water conservation. Between these two cases, a large variety of intermediate levels of exploitation of forest lands can be found. Whereas productivity is still important in the best lands, the shift in the weight of direct productivity objectives to other objectives providing goods and services with no market value so far introduce a new socio-economic framework of reference.

3.1. Criteria for afforestation and reforestation

The criteria for afforestation and reforestation should be based on the knowledge on the state of the soils and climatic constrains. Afforestation and reforestation projects must be preceded by a soil evaluation process from which potential plant dynamics can be estimated and the needs and type of soil preparation and cultural treatments can be established.

In the context of prevention and reduction of soil erosion, general criteria for afforestation and reforestation include:

√ ***To minimise impacts on soils of site preparation techniques***. In erosion-prone lands, extensive afforestation with heavy machinery often generates greater erosion problems than those initially existing in the area.

- Planting holes and contour subsoiling are suitable site preparation techniques; bench terracing and subsoiling along the slope should be avoided.
- Clearance of existing vegetation before or during reforestation actions should be minimised and it should be avoided in drylands

√ ***To improve plantation success*** and foster plant cover for accelerating soil protection

- Selection of suitable species. Attention must be drawn not only to their growth rates and easy management, but also to their potential contribution to the ecosystem functioning; the use of exotics should be avoided.
- Proper cultural treatments, including inorganic fertilisation and organic amendments - to enhance plant growth and improve soil structure and infiltration.
- Field techniques to reduce transplant shock and improve resource availability, such as tree shelters, mulches, water-catchment basin around each plant, etc.

√ To establish an appropriate trade-off between enhancing growth of target species and maintaining a minimum protective soil cover, by reducing impact on soils of thinning and clearance actions.

3.2. Soil protection in forestry. Forest management

With increasing mechanisation of forest logging the impacts on soil have also increased. Fragile soils with poor soil cohesion are very sensitive to the impacts of heavy machinery and clearance of vegetative cover, particularly on steep slopes. Sources of impacts include bank erosion, skid trails, logging roads, and timber extraction. Skid trails and logging roads have been identified as the major sources of sediment. Mitigation measures include:

- √ Application of ***reduced-impact logging*** to minimise soil compaction and rill erosion, e.g. to control the use of tractors and to design the skid trails to avoid runoff concentration lines.
- √ To ***reduce clear-cutting area***, to replace clear-cutting systems by other low-impact cutting systems.
- √ To ***vegetate barren roadsides*** as fast as possible using grasses and shrubs adapted to local climate and soil conditions and able to establish by themselves, especially in regions where the natural forest regeneration is slow.
- √ To ***divert water flow*** from the road drainage system towards the nearby vegetation, ***bringing overland flow to infiltration*** on provided areas and thus preventing the fast release of this water to streams and rivers.

Organic forest floor materials, such as litter and woody debris, play a major role in preventing soil detachment and providing surface roughness. Practices extensively altering forest floor layer should be avoided. Prevention measures should include conservation measures, such as ***spreading woody debris*** over the skid trials

Northern boreal forests are often growing on organic soils. The removal of the forest cover over large areas causes a disturbance of the hydrological balance. Ground water level is rising and prevents natural regeneration of the forest. Improvement of drainage causes the disintegration of the peat and the release of nutrients polluting rivers and drinking-water sources. There is a need of reducing the size of cutting areas to keep the hydrological balance.

Silvicultural actions –aimed mainly at fire prevention (firebreaks, roads, removal of fire-prone shrublands; see below) but also at improving stand structure– may be self-defeating actions depending on the technique and intensity applied. Vegetation removal (thinning, clearing….) should be carried out without damaging the soil surface, working at some height above surface, and spreading slash on the soil.

3.3. Forest fire prevention and post-fire management

In forest lands, mainly in Mediterranean woodlands, a major and common threat for soil conservation is fire. The sequence 'summer fires - heavy autumn rains' is frequent in Mediterranean climates. In the more fragile soils where plant regeneration rates are slow, the risk of soil erosion is extreme on steep slopes.

The current number and extent of forest fires in many parts of the Mediterranean region are of the most serious environmental problems because it can lead to irreversible soil degradation and the loss of valued environmental qualities.

It is assumed that soil erosion is the most serious ecological impact of fire because of its low reversibility. Therefore, soil conservation is the main priority in reducing the ecological impact of fire. This can be addressed by fire prevention actions and, in case of fire, by post-fire soil conservation and restoration measures; the latter may also contribute to prevention of further disturbance impacts by increasing resistance and resilience of fire-prone ecosystems.

Fire-risk countries have strongly improved the suppression resources, limiting the damages at a high cost and following a policy of total exclusion of fire. Economical possibilities to increase those resources are nearly exhausted. So, forest fire management has to find more effective approaches by improving strategies and technologies for prevention[8].

Prevention on fire causes

Uncontrolled burnings must have a specific program of prevention, because it is deeply rooted in a well-identified segment of the population, the rural one. Prevention of fires caused by uncontrolled burnings needs co-ordinated actions of persuasion, conciliation and prosecution, to modify the human behaviour of the rural population in the use of fire. This program has to be permanent and continuous, with a comprehensive planification supported by a specific database.

Persuasion aims at teaching the rural people that they are directly damaged by the fires in their ownership and environment. This can be done through a variety of awareness raising campaigns or environmental education, and by co-ordinating concerted actions by forest managers, scientific groups and administrative departments. ***Conciliation*** of interests between farmers and Administration may be promoted through a program of controlled burnings in winter. ***Prosecution*** and punishment of people burning without a license and in a careless way is the object of the Penal Codes and the Regional Administrations rules. There are very few data on this preventive action needing analysis to evaluate its effect.

Structural measures to reduce fire hazard could include the diversification of forest land use, the management of recreation and illegal dumping, and the introduction and enforcement of appropriate legal instruments.

Prevention through silviculture

Creating both horizontal and vertical discontinuities requires a variety of techniques for the elimination of flammable matter. In choosing the most appropriate techniques for each case, social, ecological and economic conditions should be borne in mind. For example, in areas of high unemployment, manual clearance is to be preferred. If there is a demand for land on which to raise cattle, ***controlled pasturage*** is likely to be a good choice, since it makes for an economic return as well as clearing fuel-break areas.

Clearing techniques should be based in a deep knowledge of the biology of the target plant species in order to optimise the treatments.

Prescribed burning is a very economical technique that nevertheless requires specific

[8] Vélez, R. (2003). Forest fire prevention in the framework of sustainable forestry. MEDRAP workshop on Prevention and Mitigation Actions to Combat Desertification. Alicante, June 2003.

training. When combined with controlled pasturage, it can be highly recommended. Prescribe burning must result in low severity fires, allowing fast plant recovery and organic horizons and burned debris remaining on the burned surface and, therefore, minimising erosion risk.

The use of ***phytocides should always be highly restricted***, in view of the cost and of the difficulty of controlling its effects outside the treatment zone.

Regarding prevention management focused on shaping woodland structure, the aim should be to ***create mosaics of species***, and to integrate other activities that ***give rise to discontinuity***, such as roads, electricity line fuel breaks, farm land, and recreational areas. Likewise, in exploiting the wood, an effort should be made to maintain its density, so as to limit undergrowth.

Wind is also a factor to be taken into account. Tall woodland is a more effective windbreak than scrubland, which is more effective than pasture. On ridges, where the wind changes, and along watercourses, which direct it, tree cover may be an important obstacle to fire, since it reduces wind speed. It is also worth keeping hillsides that face into the prevailing winds well covered with high vegetation that works as a windbreak, while opening fuel breaks on the leeward side, avoiding ridges.

Post-fire management.

It should be assumed that burned soils are highly unprotected and vulnerable to soil degradation, and therefore activities that may promote soil compaction and erosion should be avoided in the very short-term.

Burned lands should be ***protected from grazing*** until the vegetation recovers and protects the soil from erosion. In grasslands, one year is enough for such recovery but rangelands grazing must be deferred for about 2-3 years and shrublands for 4-6 years[9].

There is a moderate to high risk of rill erosion associated to ***post-fire savage logging*** that depends on the vulnerability of soils, with soils developed over marls, sandstone, and gypsum being the most sensitive. Severe logging, characterised by long log slides and high log density, very often results in severe rill erosion processes and therefore these practices should be limited in sensitive areas. However, any limitation to exploit charred wood should take into account the economic consequences for the owners that have to be compensated.

In all cases, post-fire logging should be delayed after the first post-fire rainy season to ensure some plant recovery that protects the soil surface. Vulnerable sites should be protected by conservation measures, such as ***spreading chopped wood debris*** over the log slides

4. Restoration and rehabilitation measures

4.1. Restoration measures to combat soil erosion. Watershed restoration

Restoration programmes aimed at preserving soil and water resources and controlling erosion and floods should be designed as ***ecologically sound, multi-purpose measures***, adapted to the

[9] Papanastasis, V.P. (2003). Grazing management in the framewok of sustainable management. MEDRAP workshop on Prevention and Mitigation Actions to Combat Desertification. Alicante, June 2003.

new social demands. The traditional forest restoration approach has to fully evolve to a new ecological approach based on the development of ***site-specific restoration strategies***, on a ***wide set of species*** choices, and on the introduction of vegetation according to environmental heterogeneity and natural vegetation spatial patterns, ***avoiding uniformly spacing plantings and creating landscape mosaics***, with the aim of recovering previous landscape processes.

The most suitable scale for the application of restoration programmes depends on specific objectives and threats. Degradation-risk hot spots require specific restoration actions to be applied in a very local basis. However, to obtain a significant effect on the threatened systems, the ***use of hydrological units*** is recommended. Watershed restoration typically includes the following actions: vegetation cover improvement, conservation and restoration; streambed of the secondary drainage network and plugging works; soil conservation practices; auxiliary actions (roads, fuel-break areas). This approach allows integrated management of erosion, transport and sedimentation processes

Native species offer a high potential for contributing to restore degraded ecosystems. Native herbaceous, shrubs and tree species might be used depending on the specific degradation stage of the ecosystem and the managerial objectives addressed. For seeder-dominated fire-prone ecosystems, ***reforestation with woody resprouters*** contributes to increase functional diversity and resilience.

The baseline for restoration activities should be a thorough analysis of past reforestation actions, both successful and unsuccessful experiences. In the same way, ***monitoring and data base elaboration*** should be intrinsic components of all restoration projects.

4.2. Post-fire soil conservation and restoration

The first question to address is in which conditions post-fire mitigation/restoration is needed. A second issue would be to set priorities for actions. A third question would be how to protect soils and to restore burned lands.

(A) ***Emergency treatments***. The following measures are proposed as emergency post-fire treatment[10]:

1) ***Previous assessment of site conditions*** and selection of areas with:
    a) Poor regeneration potential (e.g. low resprouter cover)
    b) High runoff and erosion risk (steep slope, compact soils)
    c) High downstream risk of damage (infrastructures, homes)
2) ***Spreading mulch*** (preferably onsite slash) to ensure immediate soil protection
3) Application of ***seeding mixtures using native species***
    a) Fast growing annuals
    b) Perennials for the persistence of soil protection
    c) Grasses and legumes
    d) Shrubs and trees to enhance secondary succession

Other hill slope and channel treatments can be applied in certain conditions: contour-felled

[10] Robichaud, P.R., Beyers, J.L. and Neary D.G. (2000). Evaluating the effectiveness of postfire rehabilitation treatments. Gen. Tech. Rep. RMRS-GTR-63. USDA, Forest Service, Rocky Mountain Res. Station. Fort Collins, USA.

logs, silt fences, check dams, contour trenches, blankets, etc. Their cost is higher than for seeding/mulching practices, they are hardly applicable to wide areas and, in some cases, impact on soils is high. Therefore their application should be clearly justified.

(B) ***Post-fire restoration actions***

Post-fire restoration strategy faces two main environmental issues: ***promotion of fire resilient plant communities*** and ***forest cover restoration***.

The introduction of sprouting trees and shrubs will enhance the ecosystem resilience after wildfires, and improve diversity and structure of these formations. Controlling (e.g. clearing) fire-prone shrublands with very high fuel accumulation combined with woody resprouter introduction could be a measure to break fire cycles.

In general, all restoration projects for burned lands in fire-prone ecosystems should take into account the principles of fire prevention, e.g. to avoid mono-specific plantations, to reduce fuel accumulator species, to promote more resilient and late-successional vegetation, and to design all interventions in the landscape so to reduce the hazard of fire spread.

4.3. Rehabilitation techniques of degraded soils.

Many areas in Europe exhibit serious soil degradation, normally due to anthropogenic disturbances. Examples in agriculture are abandoned degraded agricultural soils and salinisation by irrigation with low quality water. A particularly low resilience to disturbances due to their low organic matter levels has exacerbated degradation.

Attempts to restore degraded soils need to consider physical, chemical and biological properties. Soil organic matter may play an important role in all of these soil parameters. The improvement of soil properties by the application of organic matter can be a promising strategy in restoring degraded soils, especially in more arid regions in Europe. Different organic materials, such as municipal solid wastes, sewage sludge or poultry manure, uncomposted or composted, have been tested for soil reclamation (Annex 3). Sewage sludge represents a pollution sink in the wastewater treatment process. The higher the purification efficiency is the higher the accumulation of contaminants in sewage sludge can be. To supply organic matter, more appropriate low-emission materials are available.

The ***application of exogenous organic matter*** (EOM) may improve the resilience of soils against degradation processes, long-term improvements can only be achieved if the soils are managed in accordance with the precautionary principle to maintain soil functions on a sustainable basis. To avoid harmful changes to the soil, exogenous organic matter which originates from biowastes or biodegradable wastes shall only be applied when there will be no accumulation of contaminants in the soil (especially by application of sewage sludge, compost, animal manure or mineral fertiliser). Attention must be drawn not only to heavy metal loads, but also to organic pollutants and other environmentally harmful substances (such as xenobiotics and antibiotics) and potential pathogen bacteria, which may have a severe impact on soil born organisms and neighbouring ecosystems. However the application of suitable EOM may help to reduce the vulnerability of degraded soils against erosion processes, it will not stop them. Its ability to reduce erosion is less important than soil cover and land management practices. Hence the dominating aspects in this matter are the concerns about pollutants and hazardous substances, which may be found in some EOM. (See also task

5 report on 'link between erosion and contamination).

Establishing a washing and drainage system may reclaim land affected by salinisation. However, this may be expensive and technically difficult. A net positive cost-benefit balance might be possible when a strong improvement of socio-economic conditions is expected in the reclaimed area: economic development, fixation of rural populations. ***Salt-capturing crops*** may be a suitable treatment.

5. Other sectors

5.1. Reduction of sediment transport in drainage networks. Protection of reservoir sedimentation

Erosion should be stopped at its sources. It is wrong and partly impossible to intercept erosion material and overland flow at the lower end of an erosion system. Nevertheless it is necessary to have measures at disposal, by which an existing or developing erosion system can be obstructed as near to its place of origin as possible.

Measures for that purpose have been described above (2.1. Agricultural Practices to combat soil erosion), particularly those mentioned as “rural engineering measures”, and also measures of installing wooded and vegetation strips. Runoff on farm tracks should be brought to infiltration beside the tracks.

Generally it should be tried to prevent or to reverse concentrated transport and runoff through the landscape and to bring existing overland flow to infiltration on provided areas. The exact identification of the transport pathway helps to find the area of origin and the reason of an erosion/sedimentation event (Annex 4).

5.2. Mitigation soil erosion measures in transport and construction infrastructures[11]

Principles and basis

In many areas, soil erosion causes severe damage and high costs for society and individuals. Different types of soil erosion are frequent such as coastal erosion, bank erosion, landslides, gullies and debris flows. In the following, a common description is given on these forms of erosion, followed by measures suitable for different situations of erosion.

Detailed studies of the problem of shoreline erosion and flooding in the USA point to the fact that there is no problem until structures are built within the impact zone of storm surges or close to soft rock cliffs. The conclusion is that once such structures are built, erosion problems usually follow. This is not only true for properties like houses and hotels protected by sea defences but also for the sea defence structures themselves. Although building a sea defence can provide protection (perhaps only temporary) for a property it may also enhance the risk of erosion or flooding elsewhere along the shore. This is especially true where eroding cliffs are artificially stabilised as this ‘locks up’ the sediments reducing the amount

[11] The text is to a large extent based on and extracted by the Eurosion project, Scooping Study. Final Draft Report of September 2002

available to adjacent shores. As a result the balance between erosion and accretion will change, potentially increasing its susceptibility to erosion or flooding.

The combined effect of infrastructure development (which destroys habitat) and the erection of defences to protect them have created, in many areas, a narrow coastal zone. The difficulties of protecting this narrow inflexible barrier are increased where the natural resilience of the coast is lost as sedimentary systems. Today river canalisation, dams, irrigation works and activities in the river catchments themselves have resulted in a dramatic reduction in sediment availability on the coast. In areas where relative sea level is rising, there is a further coastal squeeze.

Measures

There is a wide range of techniques available to monitor and manage the many types of erosion and flooding that affect the coast and shores of lakes and rivers. Detection and monitoring techniques include visual observations, aerial surveys and remote sensing images, topographic and bathymetric surveys.

These coastal protection and flood defence techniques can be described in relation to the development of what are termed "hard and soft" engineering techniques. The hard engineering techniques involve the construction of solid structures designed to fix the position of the coastline, while soft techniques focus on the dynamic nature of the coastline and seek to work with the natural processes, accepting that its position will change over time.

Applying various techniques, which can be hard or soft, or a combination of both, provide the means of dealing with the problems. The solutions vary according to the local situation, but ultimately the aim is to identify the best option or options, which secure the coastline both in the interests of the environment and of people, in the most efficient and cost effective way.

An integrated Coastal Zone Management (ICZM) approach

Experience of several years of coastal protection has shown that hard engineering protection structures established by the national and local authorities along the coast, provide very local solutions which do not address the underlying cause of erosion (shortage of sediment) and generally accelerates the problem down-drift the coastal protection. To address this issue whose consequences may affect the whole lagoon ecosystem and related activities (fisheries, aquaculture, and tourism), the national and regional governments, municipalities, the harbour authority, and various universities have joined their efforts to find integrated solutions. As a result, the EU Commission has agreed on a Communication on an Integrated Coastal Zone Management approach. (COM (2000)547). ICZM is based on an integrated and broad "holistic" approach and could be an important instrument in the land use planning of coastal areas.

Coastal erosion – protection measures

As ***general principles for coastal erosion protection***, harbour authorities should apply a "sand by-passing" system through the harbour, thus reactivating the sediment transport processes. It is important to identify areas where natural coastal protection processes could be stimulated, such as dunes rehabilitated or beaches regularly supplied with non contaminated materials collected from dredging activities along navigation channels. It is also important to control illegal sand extraction activities and any other activity that may disturb natural beach and dunes restoration. Finally, the urban seafront extension should be regulated; in order to maintain protection costs at a low level.

Coastal erosion occurs mostly in areas with sensitive substrata, such as sand, silt and till or, in minor extension, soft sedimentary bedrock, especially in densely populated areas and/or in areas where buildings and other artificial constructions are located. There are several ***specific measures available*** to mitigate or protect the coastline against erosion:

- √ The most environmentally appropriate method is sand nourishment. Sand is supplied to the coast and the purpose is to compensate for the loss of sand by natural erosion. A similar method is beach scraping where the sand is moved from the lower parts of the beach to the dune foot and works as a buffer in storm situations.
- √ Revetments are structures placed at the foot of a beach slope to protect against erosion in storm situations with high water levels and big waves.
- √ Breakwaters are shore parallel structures placed along the coast. The breakwaters reduce the wave energy passing the breakwater to the coast and reduce the longshore sediment transport capacity with sedimentation as result.
- √ Groins are structures placed perpendicular to the coastline from the beach to a certain distance outside the coastline. The groin is an obstacle to the longshore sediment transport, which means a reduced retreat of the coastal profile.
- √ Vegetation is another way to protect coastal areas against erosion and this can be achieved by establishing certain plants covering the soil.

Bank erosion – protection measures

In rivers and lakes rapid runoff of water with increased speed of flow will cause erosion of the slopes of the banks and sediment transport and deposit off-site. Measures for mitigation and protection against bank erosion are:

- √ Revetments by quarry stones, concrete blocks or gabions.
- √ Nailing vegetation.
- √ In rivers where dams are situated it is important to avoid large outflows from dams in order to avoid damages downstream.
- √ Diverting the watercourse may be applicable in some cases.

Landslides, gullies and debris flows

Forces of nature are working to adapt cliffs and slopes to equilibrium. The still ongoing land uplift and shore-level displacement results in unstable conditions especially for clay and silt deposits. Construction works and deposition of heavy masses on the ground as well as excavations are other factors that can alter the stability of the soils. The frequency of landslides has in fact increased during the last hundred years of industrialisation.

A proper land use planning is the best way to prevent these types of natural hazards.

Mitigation measures in landslide risk areas can be made by:

- √ Revetments (like bank erosion);
- √ Vegetation can be established on the slopes;
- √ Soil counter weight embankments could be applied in the lower parts of the slopes or unloading by excavation of the slope crest.

In many cases the measures are combined to achieve the most effective result.

To protect against debris flow it is important to maintain existing vegetation to prevent a fast run off of surface water. Also revetments by stones or concrete can be used. Dams and energy absorbers are common measures.

Transport infrastructures.

There is a wide range of techniques available to control talus erosion in transport infrastructures. It is important to apply the proper talus slope and sequence of actions:

√ Removal and storing of the top soil prior to the works.
√ Maximum talus slope: 2/3 (vertical/horizontal).
√ Application of the stored top soil over the talus, with or without organic amendments.
√ Hydroseeding of talus, particularly in wet climates.
√ Alternative techniques such as blankets, organic nets, etc… .
√ Planting shrubs and trees, before, after or instead of hydroseeding.

6. Development of programmes in education and training

6.1. Networks and platforms for the dissemination of information and transfer of technology

It is important to consider soil degradation as an issue involving and affecting the whole society. The scientific community should be encouraged to generate information on soil degradation. The dissemination of such information is essential to create awareness of the environmental problems associated with soil degradation. Information and environmental friendly methodologies should be provided to people affected by soil degradation but especially to those at the local level, who are the most directly affected. It is important to develop regulations at the owner level that lead to the re-structuration of inadequate agro-forestry, urban and recreation use of the land. Awareness raising actions need to be targeted in their approach, particularly within vulnerable areas.

In recent decades, Mediterranean countries have made a serious effort to combat soil degradation through a wide array of technical approaches. However, most of these experiences have been developed on a national, and even local basis, with poor communication and very limited co-ordination among the various countries. Detailed databases on prevention and mitigation measures are lacking, and co-ordination between actions has been very limited. A number of actions needed can be identified:

√ Improvement and co-ordination of data on soil erosion by natural hazards.
√ Databases for integrated risk management for public accessibility.
√ Increase public awareness.
√ Analysis of the policy for public-investment and of economical effects.
√ Network for co-operation and information exchange.
√ Network between researchers, practitioners and policy makers.
√ Harmonisation of classification and terminology.

Networks and platforms for the dissemination of information and transfer of technology on prevention and mitigation measures for combating erosion are needed for the diverse activities concerned (agriculture, grazing, restoration, forest management, etc). As an example, the EC-funded REACTION project aims at building up a database of relevant information and experiences on restoration projects, and therefore at facilitating access to high quality information for forest managers, scientists, policy makers and end users.

Regarding fire risk, in too many cases heavy investments are made in fire-fighting equipment (Planes and fire engines) rather than in preventive silviculture. Measures co-ordinated among the Mediterranean countries concerned are therefore highly recommended.

Thematic permanent bodies could establish, centralise, harmonise and update databases on measures to control soil erosion, including a network of pilot projects, taking care of disseminating information for the appropriate stakeholders

6.2. Programmes in education, training and transfer of technology for farmers

Programmes in education, training and technology transfer should take into account the local situations and the socio-economic context in order to ensure that measures can be put into practice. The use of information technology, specially based on the Internet, need to be fostered in order to facilitate the dissemination of best practices. Measures/actions include:

√ **Advice/guidance booklets**. Example: Best farming practice; profiting from a good environment (Environment Agency for England and Wales).

√ **Demonstration Farms**. As an example, England has four demonstration farms across the country, which address soil management. Land managers can visit these farms and gain advice on good soil management.

√ **Voluntary Partnership**; examples: *Voluntary Initiative*, which is an industry alternative to the Government's proposed pesticide tax which aims to reduce the environmental impact of pesticides; Voluntary *Partnership - Diffuse Pollution Projects*, which are set up as partnership projects to tackle diffuse pollution on a local scale.

√ **Training from public institutions**. As examples in Northern Europe countries, both Municipalities and Extension Services in Norway support the farmers to write an Environmental Action Plan for his/her farm and take care to educate them. Extension Services make trials to show the effect of diverse measures on erosion. In Iceland the Soil Conservation Service tries to encourage responsibility of the individual land users

In practice most farmers are not aware that they have an own (financial) interest to reduce erosion and land degradation. By developing education material (national/regional) in which the on-farm consequences of erosion and the financial impact are shown, this awareness could be increased. This task may be carried out by a collaborative work of European and national Soil Conservation Services.

√ **Mapping examples**; e.g. the Norwegian Institute for Land Inventory is mapping agricultural soils in watersheds feeding into North Sea and Skagerrak, and producing erosion risk maps. The maps are free available for both municipalities and farmers.

√ **Agro-ecological decision support systems**: Soil quality evaluation and monitoring.

Emerging technology in data and knowledge engineering provides excellent possibilities in the land use planning and soil management recommendations analysis. This analysis basically involves the development and linkage of integrated databases, biophysical models, computer programs, and optimisation and spatialisation tools, which constitute actually the decision support systems.

MicroLEIS (Http://www.microleis.com), analyses the influence of selected physical indicators on critical soil functions referred to land productivity: agricultural and forest soil suitability, crop growth and natural fertility; and referred to land degradation: runoff and leaching potential, erosion resistance, pollutants absorption and mobility, and subsoil compaction. Therefore, this system appears to be an appropriate approach to develop the soil physical quality evaluation.

The case of Conservation Agriculture: some lessons

Activities that can contribute to increase transfer of technology actions are:

1) Organisation of seminars and workshops for farmers to discuss technical and environmental aspects.
2) Organisation of field days and machinery demonstrations in farms. These field days are very important for the transfer of technology in the agrarian sector.
3) Provide Training Courses for farmers and advisers.
4) Provide Topic Sheets on practical implementation.
5) Recurring edition of bulletins with news, activities, technical advances, etc.
6) Promotion of no-till clubs at local level, where farmers can directly exchange experiences.
7) Organisation of seminars for technicians from administration and private companies. For the good implementation of agri-environmental measures, it is very important that the staff of the administrations concerned have a good knowledge of the techniques.
8) Participation in fairs, conferences and seminars of importance in the agrarian sector showing stands, etc.
9) Diffusion through mass media: articles in specialised mass media.
10) Dissemination of information through Internet (web sites).

6. Soil erosion monitoring

The following approaches are recommended:

- Monitoring systems focused on prevention, mitigation and restoration measures.
- Ground-based and remote sensing monitoring.
- Ground-based monitoring sites in erosion sensitive areas.
- Assessment of erosion risk based on land use.
- Develop monitoring system in relation to water quality monitoring.
- Action-driven and multi-purpose monitoring.
- Monitoring systems performing landslide warnings based on continuous measurements of pore water pressures or deformations in the soil layers.

For ground-based approach, evaluating and monitoring soil quality is a very complex undertaking. Knowledge-based decision support systems considering separately soil physical quality and soil biological quality appear to be an appropriate way to formulate, for each unique soil, the best agricultural practices to minimise land degradation processes such as soil erosion. On this important and timely topic much needs to be done. The development and use of these computer-based tools would be one of the major tasks of a possible EU Soil Conservation Service (e.g. USDA NRCS, Http://www.nrcs.usda.gov).

The Working Group on Soil Erosion developed a detailed proposal for soil erosion monitoring in Europe, as an input for the Working Group on Monitoring within the Soil Thematic Strategy.

7. Main areas where research is needed

Mechanisms

√ To define thresholds for land restoration.
√ Interactions on soil tillage-soil quality. Possibilities of no-tillage in different ecosystems.
√ Effects of different climate change scenarios on the erosion mitigation actions.

Monitoring and modelling

√ New tools to monitor, assess, and predict soil erosion under diverse management system.
√ Development of means to monitor and measure the extent of erosion in catchments that are robust and meaningful and relatively inexpensive.
√ Sensitive biological indicators of soil quality to evaluate extensive/intensive agricultural systems. For example, to explore the potentiality of biochemical properties (e.g. enzyme activities) in the assessment of soil quality.
√ Development of models (for practical use) for predicting linear soil erosion (rills, gullies), especially regarding their ability to break through till surface waters.
√ Development of models (for practical use) to assess the connection between soil erosion on agricultural land and sediment load of rivers.

Preventive measures

√ Develop new knowledge and implement existing knowledge in land-use planning.
√ Develop new preventive and mitigation measures against soil erosion for European conditions.
√ Development and implementation of land use DSS tools to formulate sustainable soil use and management systems.

Risk analysis

√ Improvement of hazard, consequence and risk mapping methods.
√ Identify areas and situations with high vulnerability.
√ Identify acceptable risk levels.
√ Cost-benefit analyses.

Others

Today, the use of new herbicides is drastically changing the methods of crop production, without knowing exactly their impacts on soil quality/degradation. Soil contamination risk by herbicides must be deeply analysed.

In Conservation Agriculture, there is a clear need of applied research for the practical implementation in different agro-ecosystems, providing farmers with recommendations on fertilisation, control of weeds, machinery. Effective weed management is needed for the correct adoption of zero tillage system. Emphasis is needed in research at farm level.

There is also a great need to investigate the 'side effects' of CA regarding the net greenhouse gas effect (carbon sequestration versus N_2O & CH_4 production).