*ACTION ForC:* **Assessment of indicators related to carbon cycle of managed forests**

**Description:**
Forests are a key component of the global carbon cycle. It has been estimated that of the 480 Gt of carbon emitted by anthropogenic activities (fossil fuel and land-use change related emissions) since the start of industrial revolution, 166 GtC (35%) have been absorbed by forest ecosystems, 124 GtC by oceans (25%), while 190 GtC (40%) remained in the atmosphere, causing the relevant increase of $CO_2$ concentrations that is the main driver of climate change (House et al., 2002).
In this respect, the role of managed forests is crucial as several studies attributed to the forests of the Northern hemisphere, a large part of which is managed, a prominent role in the carbon cycle of the last 20 to 30 years (Schimel et al, 2001). Nevertheless, the productivity of managed forests has increased in the last years, both at European (Spiecker et al, 2002) and on a global scale (Boisvenue and Running, 2006). About the possible causes of increased productivity, a model analysis attributed 100% of the variation in temperate forests to management and land-use history, while in more natural ecosystems (tropical and boreal forests), a large part of the increase could be related to the increase of atmospheric $CO_2$ (Ciaos et al, 2005). Among the other factors, nitrogen deposition has been recently reported to play a relevant role for carbon absorption over the forest rotation cycle (Magnani et al., 2007)
Forest management has gained further importance for mitigation of climate change following the approval of the Kyoto Protocol (1997, entered into force in 2005), where articles 3.3 (Afforestation – Deforestation - Reforestation) and 3.4 (forest management and other land-use practices) attributes an important role to human-induced land-based activities that can be used to generate carbon credits to compensate emission reductions.
At European level, the adoption of the Improved Pan-European Indicators for Sustainable Forest Management by the Ministerial Conference on the Protection of Forests in Europe (MCPFE, 2002) where Criterion 1 “Maintenance and Appropriate Enhancement of Forest Resources and their Contribution to Global Carbon Cycles” is directly related to carbon and, later, the development of the EU Forest Strategy (COM (2005) 84) and of the EU Forest Action Plan (COM (2006) 302) has lead to improved consideration and awareness on the importance of forests and forest management to maintain and appropriately enhance biodiversity, carbon sequestration, integrity, health and resilience of forest ecosystems at multiple geographical scales (multifunctional role of forests).

It is then relevant to improve our understanding of carbon stock and stock changes in managed forests and how different management practices may act in maintaining and enhancing carbon sequestration in the tree, roots and soil compartments of forest ecosystems. The Action ForC will be devoted to assess how forest management can influence carbon cycling of forests, by monitoring indicators related to forest carbon. Indicators will range from the basic one of MCPFE (1.2 Growing Stock; 1.4 Carbon stock for biomass and soil) to indicators connected to carbon cycle processes of carbon stock change, such as Growing Stock change, Net Primary Production (NPP), Leaf Area Index (LAI), soil $CO_2$ emissions (before and after forest management), harvested biomass/volume, biomass of woody debris, litterfall. Methods will range from classic forest inventory approach (structure, stocks, increment) to biomass and production assessment to detailed assessment of soil carbon and up to measurements of carbon fluxes using soil cuvette and mobile systems to compare the different treatments.
Measurements will be supervised by experienced staff and grant-holders, basic data will be collected by local staff and Inventory Teams of the CFS. For some of the more detailed indicators on carbon cycle, rowing team of grant-holders will visit the selected plots.

The action will be devoted to assess biomass and carbon related parameters.
Classic forest inventory techniques will be applied before and after the management operations and, for the test areas treated in the first phase of the project, also in the last project year.
Soils will be sampled at all sites at least once (15 to 25 samples/test area) and before the end of the project for the test areas where management will be performed first. At two contrasting

sites we plan a larger sampling scheme (up to 80 to 100 samples per area) in order to try to discriminate possible difference after 4 years.
Chemical analysis in the laboratory for Carbon concentration of biomass components and soil: approximately 1000 analysis will be performed
Leaf Area Index at season peak at all test areas, at least twice during the project
Line intercept and area-based methods for woody debris: once before and once after management operations at half of the test areas.
10 to 15 Litter traps will be installed at half of test areas. Traps will be emptied every 2 months
Soil CO2 emissions with soil cuvettes on two to three test areas (three different management options at each area). Monthly measurements on 15 to 20 points.
Carbon fluxes at canopy level with mobile system: one or two test areas, almost continuous measurements

The basic indicators related to forest carbon cycle will be assessed on all the areas of the project in the six UTB district. Some of the more specific and complex indicators (e.g. flux measurements, detailed geostatistical sampling of soil carbon) will be assessed on selected areas, according to specific conditions.

Action ForC will start at month 7 and last until month 54.

**Methods employed:**
- selection of indicators (see also Action PA)
- setting up of sampling scheme and protocols (see also Action PA)
- classic forest inventory methods applied with the help of the Inventory Teams of National Forest Service
- sampling and analysis of soil
- chemical analysis in the laboratory for Carbon concentration of biomass components and soil
- measurements of Leaf Area Index with optical techniques
- line intercept and area-based methods for woody debris
- litter traps for litterfall on selected cases
- geostatistical methods for spatial variability of sparse data of biomass and soil organic carbon and their mapping through spatial interpolation at selected cases
- soil CO2 emissions with soil cuvettes on selected cases
- carbon fluxes at canopy level with mobile system on selected cases

**Constraints and assumptions:**
The Action will rely on the timely execution of surveys that, in some cases, have to be performed before and after forest management operations. Part of these duties will be performed with the cooperation of the personnel of the UTB and Inventory Teams of CFS, responsible for managing and control the forest areas where the project will be carried on. Inventory Teams are often tightly connected to local offices. Grant holders will be crucial for the assessment of some indicators and for data elaboration. Possible delays in the hiring procedure could result in slight delay of surveys but it is not expected that this will cause major problems to the project.

**Beneficiary responsible for implementation:**
CNR
Other Beneficiaries involved in the Action: CRA, UniMOL

**Expected results:**
- MCPFE Indicators on the carbon cycle in managed forests
- indicators on some detailed processes of forest carbon sequestration and/or emissions
- Leaf Area Index and woody debris of differently managed forests
- data on biomass and soil carbon stock and stock changes in differently managed forests along geographical transects
- report on the effect of forest management options on the carbon cycle of forests
- determination of change from the baseline (reference management options or no intervention)

**Indicators of progress:**
Number of plots measured for basic indicators
Number of plots assessed for more detailed indicators
Measurements before performing forest management operation: 30% of sites before July 2012; 60% of sites before July 2013; all sites before June 2014.
Measurements after forest management operation have been performed: 30% of sites before Jan 2014; 60% of sites before Dec 2014; all sites before May 2015.
Second sampling at sites where management operations will be performed first: all sites before June 2015

*ACTION ForC-SI:* **Assessment of indicators related to carbon cycle of managed forests**

**Description:**
The detail description of action *ForC-SI* correspond to the action *ForC.*

Measurements will be supervised by experienced staff and grant-holders, basic data will be collected by local staff and Inventory Teams of the by SFS in co-operation with SFI and BF. For some of the more detailed indicators on carbon cycle, rowing team of grant-holders will visit the selected plots.
The basic indicators related to forest carbon cycle will be assessed on all the areas of the project. Some of the more specific and complex indicators will be assessed on selected areas, according to specific conditions.

The action will be devoted to assess biomass and carbon related parameters.
Classic forest inventory techniques will be applied before and after the management operations and, for the test areas treated in the first phase of the project, also in the last project year.
Soils will be sampled at all sites at least once (15 to 25 samples/test area) and before the end of the project for the test areas where management will be performed first. At two contrasting sites we plan a larger sampling scheme (up to 80 to 100 samples per area) in order to try to discriminate possible difference after 4 years.
Chemical analysis in the laboratory for Carbon concentration of biomass components and soil: approximately 400 analysis will be performed
Leaf Area Index at season peak at all test areas, at least twice during the project
Woody debris: once before and once after management operations at half of the test areas.
10 to 15 Litter traps will be installed at half of test areas. Traps will be emptied every 2 months
Soil $CO_2$ emissions with soil cuvettes on two to three test areas (three different management options at each area). Monthly measurements on 15 to 20 points.

Action ForC will start at month 7 and last until month 56.

**Methods employed:**
- selection of indicators (see also Action PA, PA-SI)
- setting up of sampling scheme and protocols (see also Action PA, PA-SI)
- classic forest inventory methods applied with the help of the Inventory Teams of SFS, SFI
- sampling and analysis of soil
- measurements of Leaf Area Index with Win Scanopy technique
- line intercept and area-based methods for woody debris
- litter traps for litterfall on selected cases
- soil $CO_2$ emissions with soil cuvettes on selected cases
- chemical analysis in the laboratory for Carbon concentration of biomass components and soil

**Constraints and assumptions:**
The Action will rely on the timely execution of surveys that, in some cases, have to be performed before and after forest management operations. Activities will be performed with the cooperation of the personnel of the SFI, SFS and Inventory Teams, responsible for managing and control the forest areas where the project will be carried on. Grant holders will

be crucial for the assessment of some indicators and for data elaboration. Possible delays in the hiring procedure could result in slight delay of surveys but it is not expected that this will cause major problems to the project.

**Beneficiary responsible for implementation:**
SFI with external collaborator (SFS, BF)
The Associated Beneficiary SFI planned cooperation with SFS (Slovenian Forest Service) and BF (Biotechnical Faculty, Department of Forestry and Renewable Forest Resources) experts to carry out action activities that are expressed in the breakdown of costs, allocating a portion of budget as external assistance costs (close to 10% of the budget).
In this respect, external costs will cover payment for the expected/agreed work with defined hourly rate/ fee, travel costs, needed to cover daily allowances according to the national legislation Specific work: help on the field for measurements. Assistance in data entry, technical support in the field. Support for sampling. All the external assistance will be awarded in agreement with existing regulation for public tendering.

**Expected results:**
see Action ForC

**Indicators of progress:**
see Action ForC