Sustainable use of natural resources
Forests and other plant material

1. Executive summary

The Swedish University of Agricultural Sciences (*SLU*), its partner Umeå University (*UmU*) and the Forestry Research Institute of Sweden (*SkogForsk*) jointly present a comprehensive proposal within the area *Forest and other plant material* under the heading *Sustainable Use of Natural Resources.*

Forestry and agriculture are the basic and most important activities that aim towards a sustainable bio-economical society in the future. This development has to be supported by high quality science producing critical knowledge about renewable and biodegradable resources that can be used for building a sustainable future. *SLU,* together with its partners, have the best possibilities of all universities to further develop the scientific knowledge base within *Forests and other plants*. It has unique infrastructures with research parks, environmental monitoring programmes, e.g. the National Forest Inventory, and ongoing long term experiments that form the necessary base for future steps. *SLU* and its partners also have excellent laboratories, facilities for controlled growth of plants, technical platforms, and extensive international collaboration that will enable this initiative to deliver high quality science. *SLU* and its partners have very good contact and cooperation with industry to produce innovative products for the future. The overall grand goal of this initiative is to create an *internationally leading scientific environment for sustainable development* in Sweden, enabling renewable plant resources to be used in an environmentally friendly way to pave the way to new innovative high-value products that will substitute non-renewable sources. We will create a scientific environment that will attract young scientists and experts and increase international cooperation, cooperation with industry and possibilities for the future.

The initiative is built on existing *Centers of Excellence* at the Universities that deal with forests and other plants, e.g. the newly started large programmes *Future Forests - Sustainable Strategies under Uncertainty and Risk* and *Umeå Plant Science Centre (UPSC)*, which includes the *Berzelii Centre for Forest Biotechnology* and *FuncFibre*. The programme is also directly connected to the European comprehensive programme *ICON* dealing with vegetable oils. Furthermore, it is also built on ongoing extensive international co-operations.

The strategy is that this initiative will create added value where scientists from different disciplines will interact to address fundamental questions concerning the role of forest and other plants for sustainability. The initiative is built on four cornerstones *i*) excellent science, *ii*) focussed research, *iii*) industrial connections, and *iv*) recruitment of young PhD students and scientists to a coordinated scientific environment with international co-operation.

The research in this initiative will be focussed within four themes, *i*) Impact of climate and nitrogen on carbon dynamics in forests *ii*) Forest genetics and the next generation of forest trees, *iii*) Sustainable and adaptive forest management and *iv*) Other renewable plant resources, non-food crops. The objective is to develop the basic knowledge foundation regarding fundamental aspects of forests and other plant materials, and to apply this knowledge to aspects dealing with sustainable economic and environmental management of

the ecosystems as well as innovative high-value (added) industrial products. This will be achieved through coordination and gathering of research in Sweden related to production of forests and non-food crops for the bio-industry.

The task of intensifying forestry to produce more timber, paper, and energy, while at the same time ensuring ecosystem services, such as biodiversity, water quality, wildlife, and recreation, is complex. Difficult decisions have to be made if we are to strike a balance between these demands. These decisions have to be supported by scientifically-based adaptive forest management coupled to land-use strategies to deal with trade-offs on different scales. Increased production of forest raw material is possible to achieve in an environmentally friendly way, but the knowledge base needs to be increased. Forest scientists will deal with questions from the regeneration of trees with known traits to the risk analysis of the whole system. An increased production and environmentally friendly regeneration of forests involve development and application of knowledge from many disciplines, from single plant growth processes up to land-use on landscape scales. Moreover, the production research is dependent on possibilities to make both small- and large-scale experiments. A stable and secure production in the future can be achieved by developing existing and new techniques, increasing the genetic potential of trees and through enabling mass-propagation of trees with desired traits. Increased production also results in an increased sequestration of carbon in forests. Such increases of production and carbon sequestration in turn will depend on increased use of nitrogen fertilisers in forests and therefore, a critical aspect is how nitrogen can be managed in forests to maximise such benefits, but minimise negative side-effects. Thus, a sustainable production includes research targeted on effects on the ecosystem and the risks that exist; hence these questions are also addressed in the current project proposal.

This proposal also concerns research on other plants than trees. Green biotechnology paired with expertise knowledge of the basic metabolic pathways will lead the way to produce new tailor-made materials for use as feed-stocks in the industry, such as vegetable oils, sugars, starch, and plant sterols with specified qualities. Protein rich rest products can be used in innovative ways and replace material from non-renewable sources. Plant fibers of different properties and with tailor-made qualities can also be produced. *SLU* and its partners have strong competence and cutting-edge technology to investigate how material can be processed to innovative and attractive products for the future. The research group is also competent in developing specific cultivars, and to grow crops in a sustainable manner.

The budget for the period 2009 - 2013 is estimated to a total of 140 million SEK, of which 80% is allocated to *SLU* and 20% to *UmU*. Together the universities will support *SkogForsk*, with 1.5 million SEK per year, for an academic position in forest tree breeding. The main part of the budget is reserved for recruitment of researchers, especially to give extra possibilities for young researchers. We will also recruit senior researchers in strategic areas in the spectrum from field experiments to work on molecular level. This initiative will strengthen and increase the value of already ongoing research. It will support the future with new scientists recruited from PhD schools. The initiative will test new concepts and ideas in close collaboration with international experts and the industry.

This initiative will contribute to take Sweden to an internationally leading position in *Sustainable Use of Natural Resources* by developing the area *Forest and other plant material*.

2. Research programme

2a. The Universities plan to develop leading-edge research in the area

With regard to the specific research topics addressed in this application "***Forests and other plant material***", excellent research areas are already present at *SLU* and *UmU*. An agreement exists between *UmU* and *SLU* to promote science for sustainable development. Scientists from *SLU, UmU,* and *SkogForsk* are participating partners in this application, with full support from the universities and the institute. The research outlined also has a broad support from important industrial companies (see enclosed letters of support).

This jointly presented initiative is built on ongoing research at *SLU* and *UmU*. The twouniversities have an established successful cooperation within Umeå Plant Science Centre (*UPSC*) (http://www.upsc) and the newly started *Berzelii Centre for forest biotechnology* supported by VINNOVA (Swedish Governmental Agency for Innovation Systems) as well as strong support from the Swedish forest industry. *SLU, UmU,* and *SkogForsk* have an ongoing collaboration in the newly started programme *Future Forests - Sustainable Strategies under Uncertainty and Risk* supported by MISTRA (The Foundation for Strategic Environmental Research) and the Swedish forest industry. *Future Forests* is the largest and most comprehensive forest research programme ever in Sweden, with a turnover of 150 million SEK in the first phase.

For the forest part of this application, a close co-operation between leading scientists and collaborators from *SLU, UmU,* and *SkogForsk* is a necessity. It is partly built on the unique five-year PhD- research school – *Forest genetics and Tree Breeding*, (www.resschool.slu). Forest enterprises play a central role as host companies for the PhD students. The Swedish forest industries participate in this programme and are represented in the board of the Centre. For the "other plants" part of this application, co-operation is ongoing in many aspects with different industries, most visible within the EC-FP7 project *ICON*, dealing with development of plant oils for industrial use. This programme has a turnover of 100 million SEK and has 23 partners co-ordinated by one of the participating researchers in the current programme. A number of companies support the research.

SLU and its partners aim to further develop its basic knowledge base in this application within four themes dealing with fundamentals of forests and other plant materials. We intend to couple this knowledge to applied aspects dealing with sustainable economic and environmental management of the ecosystems as well as innovative industrial products. In this application we describe the added values and the development of a strong international research platform that will give young scientist good possibilities for the future. This initiative is also built on ongoing international co-operation.

A common insight for this platform and the researchers participating in different themes is that a competitive industry, based on natural renewable resources, must have a solid knowledge base about the production of raw material and its qualities, top competence and cutting-edge technology to process the material to innovative and attractive products for the future. It must also have knowledge and tools to ensure that negative effects of these activities on ecosystems are minimised.

Forest and other renewable plant resources and the understanding and sustainable use of them are key topics for *SLU* and its partners. The proposed research programme is divided into four main themes, which are briefly presented below.

Theme 1 - The impact of climate and nitrogen on carbon dynamics in forests

Sustainable forest production requires efficient utilisation of environmental resources on local as well as regional scales. This, in turn, requires a better appreciation of the links between site conditions and forest management and an increased understanding of how high-productivity stands can be integrated in a landscape perspective. A critical aspect of forests and forest management is how they are affected by, and how they themselves affect, climate change via the carbon (C) and nitrogen (N) cycles. Understanding the outcome of interactions between the cycles of C and N in and through forests is of vital importance for the development of sustainable silvicultural systems, for decisions on whether forests should be fertilized to sequester more C, and for predictions of future effects of N deposition and climate change on forest growth. The balance between rates of photosynthetic C gain and respiratory loss of C is strongly affected by N dynamics. Experimental studies of coniferous forests where C and N accounting is possible suggest a strong positive effect of added N on C accumulation with a ratio of accumulated C to added N of 30-50 kg C per kg of N. These results highlight the critical role of N as a limiting factor for forest growth. Moreover, the positive effect of N fertilisation on the C balance of forests may be offset by increased emissions of N_2O from the N-fertilised stands or neighboring ecosystems, by loss of biodiversity and by eutrophication of aquatic environments. Contributing to the perturbations in the N-dynamics of forests, human impacts on the global N cycle have increased exponentially since the 1950s, now contributing more than half of the annual N input to the biosphere.

It is clear that the need to mitigate global perturbations of the C and N cycles, an escalating pressure on forests to generate feedstock to industries, and a need to preserve forest environmental quality can only be met through an increased understanding of how C and N cycles are coupled in these systems. Recent advances in our understanding of biogeochemical C and N cycling in forests suggest that these two cycles are even more directly linked than previously thought. Thus, soil respiratory fluxes contribute a substantial fraction of total ecosystem respiration, but are highly dependent on N availability. This dependence is geared through the effect of N supply on tree C allocation so that at high N availability, fluxes of C to belowground structures and activities are sharply down-regulated. The actual mechanisms underlying this shift in allocation, with large impacts on both autotrophic and heterotrophic respiratory fluxes, are largely unknown. Thus the above-belowground interface and the root-fungal interface are two important determinants of, and focal points for our research on C - N interactions.

Addition of N lead to increases in above ground growth, foliar biomass, increased concentration of major enzymes involved in photosynthesis and a change in allocation of C with more C being allocated above ground in, e.g. tree stems. The latter occurs at the expense of allocation to roots and mycorrhizal fungi. However we still lack fundamental understanding of how increased N translates into increased growth. Only a small fraction of applied N (10-20%) is actually recovered by trees. From a tree-growth perspective, this problem has two aspects; *i*) why can trees, which dominate the forest ecosystem in terms of biomass, not acquire a larger fraction of the added N?, and *ii*) how can the relatively small fraction of N that trees acquire still result in such a pronounced growth response? We suggest that detailed studies of N uptake processes by trees and their mycorrhizal symbionts are needed to answer the first question. Answering the second question involves studies of short-term responses of trees to shifts in N supply rates and involving studies of genes, metabolites, and physiological responses

A low recovery of added N could result from a poor transfer efficiency of N from the fungal symbionts to the host plant. It has also been speculated, based on the vertical distribution of ^{15}N natural abundance in forest soils, that fungal N may be a major precursor of stable N in soils. Moreover, we have shown that gross N mineralisation, a pivotal process, is strongly negatively correlated with the ratio fungi-to-bacteria. Altogether this suggests a key role for the belowground C allocation to ectomycorrhizal fungi in controlling N transformations in coniferous forest soils. This is a new conceptual framework, which will serve as a background for the work. A potentially very important route of N loss from ecosystems is via formation of the potent greenhouse gas N_2O which recently also has raised concern over the greenhouse-gas balance of biofuel production systems based on agricultural crops. In forest ecosystems, with the important control by the fungal community of the N cycle, denitrification will be strongly dependent on the interactions between trees, their ectomycorrhizal fungi, and other organisms involved in key N transformations. The bacterial communities in particular nitrifiers and denitrifiers will be studied using molecular methods.

Given accurate net productivity values and knowledge of energy (C) and nutrient transfer efficiencies for species and trophic levels in an ecosystem, it would be possible to understand the relative importance of different transfer pathways and predict ecosystem responses to altered C to N supply. However, plants and microorganisms exhibit inter-specific differences in their efficiencies to assimilate C and nutrients, and to decompose organic material. This implies that species composition of plants as well as of soil microbes will influence both the rate and the magnitude of these fluxes. To understand the importance of species diversity (and composition) we need to study these fluxes at all trophic levels simultaneously, i.e. in both above- and belowground compartments.

We have unique access to methods and field trials that will enable us to link studies at the gene and molecular levels to studies of C and N fluxes at a stand level. Our aim is to integrate and scale the individual processes in ongoing long-term field manipulation trials such as the Flakaliden nutrient optimisation experiment, but also in a recent N-deposition and fertilisation trial, where we study compartmental C fluxes in a managed Scots pine stand using eco-physiological and eddy-covariance techniques. For the integration of results, from different levels of resolution in space and time, process-based simulation models are used.

In long-term manipulation experiments with opitimised and balanced nutrient supply, a more or less complete accounting of effects of added N on C fluxes and C storage is now emerging. The drastic increase of aboveground biomass production, is mainly the effect of increased leaf area index, but partly a result of the above-mentioned shift in C allocation and by the decrease in soil respiration. The changes in trees, understorey vegetation, and in the belowground communities following fertilisation, all contribute to a range of effects on the stand level.

The range of studies suggested here will generate results that will guide how these effects shall be optimised to achieve increased biomass production, C sequestration and sustained ecosystem structures and functions.

Specific research questions:

- What mechanisms drive N induced shifts in C allocation?
- What mechanisms affect tree acquisition of different N sources?
- How does microbial community structure influence N immobilisation, N mobilisation, N accumulation, and N loss from coniferous forest soils?
- How do microbial community composition and N supply rate interactively determine nitrous oxide emission from forest soils?
- How can linkages between plants and microorganisms drive N induced vegetation change?

- How is the biodiversity of forest understorey affecting, and affected by C and N cycling in forests?

Theme 2 - Forest genetics and next generation of forest trees

Through the creation of new varieties of forest trees, tree breeders have played and will continue to play an important role in improvement and sustainability of forests. A large collection of varieties are tested in the ongoing long-term experiments at *SLU* and *SkogForsk*. Genetics and combined sciences have continuously developed methodology to recombine, test, evaluate, analyse, select, and propagate tree species. National teams seldom reach critical mass to conduct their activities efficiently. In addition tree breeding R&D activities become more complex do to environmental concerns (e.g. climate change) socio-economic pressure and development of new technologies (e.g., genomics, somatic embryogenesis). This is also true for Sweden. This initiative will create a base for development of a critical mass of scientists within tree genetics by strong collaboration between academia, practical tree breeding and development of new technologies paired with a strong international collaboration (e.g., ongoing EU programmes such as *Treebreex, NovelTree* and others in US, Canada and Australia).

Genomics

Despite the importance of understanding the genetic basis of important ecological adaptations that can help mitigate effects of future climate change, relatively little is known about the genetic architecture of such traits in natural forest populations. Today, phenotyping is the weak link in association genetics and improving phenotyping by quantitative genetics theory will be valuable. The wealth of molecular markers made available by recent developments in genomics has opened up the possibility to directly study associations between alleles and adaptive traits in natural populations (association mapping).

The *Populus* genome programme has motivated us to embark on a similar project for a conifer species, and this initiative will focus on Norway spruce (*Picea abies*). We already have access to spruce DNA microarrays through collaborative agreements with the *Treenomix* project at University of British Columbia, Vancouver, Canada. A full genome sequence is clearly needed. Sequencing of a conifer genome has so far been a project beyond the capacity of the scientific community, however, rapid development of new DNA sequencing technologies are making plans to obtain a full genome sequence realistic within the next 2-5 years. Funding outside of this proposal will finance the budget for this project, but if resources from this application would be available it will be used to strengthen our expertise in conifer genomics and bioinformatics. A strong focus will also be on the development of genomics-assisted breeding methods in Norway spruce. Here new resources will be needed to strengthen the links to the operational tree-breeding programme.

Understanding the biological processes that determine plant growth and productivity requires an integrative approach. This knowledge in turn needs to be coupled to a mechanistic understanding of the molecular-genetic pathways affecting metabolic processes, which requires expertise in the regulation of plant development, cell division and cell expansion as well as techniques needed to identify key regulators of development, e.g., nutrient uptake, allocation and photosynthetic efficiency. All these competencies are available within groups involved in this application.

Based on ongoing research in the *Berzelii Centre for Forest Biotechnology* the focus will be on a complete and comprehensive analysis of transgenic aspen with enhanced biomass production potential and altered patterns of growth and carbon allocation. This is done in close

collaboration with the forest-biotechnology company *SweTree Technologies (STT)*, and utilising a world-unique bio-bank of transgenic trees affected in the expression of 2000 individual genes, linked to the regulation of growth and wood formation. The role of different nitrogen-containing molecules as signaling compounds in order to drive biomass allocation and the shaping of plant growth will be analysed in order to understand how different nutrient regimes can be used to stimulate the growth of plantations of forest trees into producing trees with certain desired properties. Field testing of such plantations, together with field testing of genetically modified trees in order to evaluate both possibilities and potential risks of genetic modification, is done in close association with the expertise at *SLU* and *SkogForsk.*

Mass-propagation of trees, somatic embryogenesis and transformation

Somatic embryogenesis (SE) in conifers will be used in the future for large-scale clonal propagation, for production of trees with superior traits including transgenic trees. This initiative will focus on *i*) understanding the cellular and molecular mechanisms regulating early embryo differentiation *ii*) establishing automated mass-propagation techniques of embryos of coniferous trees. This first aspect will be studied in the SE-laboratories and research groups in both Uppsala and Umeå and for the second aspect the techniques will be developed within the SE-laboratory in Umeå in close collaboration with the company *STT* and other forest industry partners. The full potential of genetic engineering will be achieved with the integration into conventional breeding programmes. Researchers within this initiative have developed methods for producing transgenic spruce valuable for studying e.g., phase changes, phenology, wood formation and resistance and will be used for an extensive comparative biology approach. Somatic embryogenesis in Norway spruce has been developed as a model system for studying embryology in conifers. Our strategy is to exploit this model system for elucidating important processes that regulate embryo development, to make the technology more efficient, including the possibility to make somatic embryos from mature adult tissues such as needles.

Improvement of wood and fiber quality for future use

Not only is the amount of wood production an important target but also enhancing the quality and modifying its chemistry for added value is becoming increasingly important. Developmental regulators such as plant hormones and downstream transcription factors is a research area where scientists involved in the Centre of excellence *FuncFibre* has a long track record and a continuous production of novel findings. The focus in this initiative will be on genes modifying fiber morphology that have been identified and this will allow new strategies to produce wood fibers for different end uses. Another area where rapid progress has been made is in understanding the regulation of primary and secondary wall formation by a multitude of genes involved in carbohydrate and cell wall biosynthesis. Together, all these data generated will be used in order to create the next generation of ”*tailor-made trees*“ designed in order to fulfill the need for a certain end product, whether it is wood for pulp production, construction materials or wood ideally designed for ethanol or other bioenergy products. The basic research on wood cell wall biosynthesis will also be useful in producing feedstock suitable for new materials. Biological processes of interest are increased lignin for high energy content, and altered relation between hemicelluloses and cellulose, which is of great importance for thermochemical wood processing. The acetylation of xylan, cellulose crystallinity and the structural composition and interlinkage between the wall polymers are critical for wood biorefining to various products and materials, such as biofuels and nanocellulose based materials. Moreover, discovering novel enzymes functional in wood biosynthesis are potential tools in modifying wood fibre surfaces to add physical and chemical properties of high value. Novel enzymes can also be explored for various biorefining processes.

Chemicals from trees

Trees offer one of the best production systems for obtaining large amounts of a variety of chemicals. This will be one of the novelties in this initiative. The group of Prof. Stymne has since several years worked with enhancing lipid/oil production in plants and also producing novel types of oils using metabolic engineering. Building on this data from collaborative project has been started on using trees as a production system for synthesis of oils and lipids. In a proof of concept work, funded by SSF, the first step taken is to alter metabolic pathways to divert excess starch towards the synthesis of lipids (through use of lipid biosynthetic enzymes expressed in model plant poplar as well as key regulators of lipid biosynthetic pathway encoded by transcription factors). This work will be extended further in this initiative to not only enhance lipid/oil levels in trees thereby increasing their energy value, but also eventually to produce quality oils in the future. Following the proof of concept experiment the system will be transferred to high biomass producing trees generated in a collaborative research between academia and industry involved in this initiative.

Development of knowledgebase to control of growth and development

There are several key aspects of significant basic biological interest that distinguishes annual plants from perennial plants, like the trees. These are also traits of significant importance for future designs of new more efficient breeding strategies in order to enhance the speed of tree breeding and to breed for new varieties that are better adapted to a changing climate.

Several subject areas can be listed and this initiative will focus on:

- *Juvenility-to-maturity transition* in trees. Not only flowering, but also other biological properties show this late transition. Genetic and hormonal factors that are involved in these transitions will be examined.
- *Regulation of plant flowering.* A comparative biology approach where the functional conservation of genetic pathways controlling flowering are studied in *Arabidopsis, Populus* and spruce are the priority.
- *Growth and dormancy*. One of the foci is on the unique feature of tree stem cells to cycle between active and dormant states. Another focus is on the genes regulating the secondary growth of the stem.
- *Timing of growth cessation and bud break.* Day-length and temperature regulation of the signals that regulate bud set and bud break and the natural variation in this trait is of basic importance.

Taken together, these studies will be central for our ability to understand and model how the forests trees and other important crop plants will respond to climate change e.g. warming and nitrogen deposition.

Theme 3 - Sustainable and adaptive forest management

The use of highly genetically improved seeds and seedling is suggested to improve production potential considerably. However, the gain would not be manifested until survival in the field can be considerably improved and a greater knowledge of this issue is necessary in order to better understand patterns of forest regeneration, productivity and the mechanisms, which restrict seedling growth and survival. Although new forests regenerate in the majority of logged areas, our knowledge about factors that restrict tree seedling growth is surprisingly poor. A better understanding of ecological processes that regulate management of forest ecosystems will improve both productivity and biological values more quickly and effective.

This theme aim at enhancing our basic understanding of ecological factors that are crucial for the development of more effective forest regeneration. In order to be prepared for an uncertain future, we need to combine different regeneration techniques into new, more flexible regeneration methods. The initiative will specifically focus at addressing questions that improve the knowledge about how tree seedlings respond and recover following various disturbances including those of a changed climate. Better understanding of germination and growth of natural regenerated seedlings of various tree species is needed as well as knowledge about the most important damaging agents affecting mortality, e.g. damage by pine weevils in planted conifer plantations and the role of ground layer vegetation for establishment of natural regeneration. Furthermore, the process of ingrowth of new trees in forest stands must be understood in order to be able to predict development of continuous cover forestry.

Management of young stands sets the arena for forest production e.g. by choosing tree species composition and tree-density at pre-commercial thinnings. Therefore, management of young stands cannot be treated separately from activities during the rest of the rotation period. A good understanding of forest stand dynamics is necessary. A large data-base from numerous pre-commercial experiments that were established during the last 50 years has recently been made available. This database together with new field experiments that aim at a better understanding of stand dynamics in young monoculture and mixed species stands will be used in order to increase our knowledge on the interaction between management in young stands and dynamics in mature stands.

At the *Faculty of Forest Sciences*, we have a long tradition of forest management research. Data from long-term thinning experiments, National Forest Inventory, *Future Forests*, and eco-physiological studies of forest stand dynamics will form the basis for development of new management programmes that will address new silvicultural goals, e.g. carbon sequestration, preservation of biodiversity, social values and production of bio-fuel. Management methods for a multifunctional forest must be evaluated both from an economical point of view, a technical point of view and from its effects on uncertainty and risks.

Increased forest production can be achieved in many ways. Fertilisation of forest stands is an important way to increase production of stands that will be harvested in the near future.. Interactions between fertilisation and forest management treatments, such as thinning, rotation age, and whole-tree harvest need to be investigated more thoroughly. In addition, forest production may be increased by choosing genetically improved material and high producing tree species and by improving site conditions by e.g. drainage. Harvesting biomass in dense, young stands is one way to rapidly increase harvestable production in Swedish forests and whole-tree harvest, including the root-system, is another way to increase immediate supply of biomass. The possible consequences on soil and surface water quality are therefore of importance to study further. New silvicultural systems that are securing biodiversity, future production, social values, and water quality need to be developed in order to achieve this. New technical solutions (e.g. GIT technology, laser scanning etc) that are tailored to be used in new silvicultural systems are also under way. Such research including new machines are currently developed the innovative programme IFOR (Intelligent Vehicles Off Road) at *UmU*. Collaboration with this programme is planned.

A challenge of forest resource management today is to operate under rapidly changing environmental, regulatory, and economic conditions, where empiricism is complemented with new and innovative approaches to forest management. Understanding response processes to change is thus crucial for designing efficient decision support systems that can help build adaptive capacity. It is also part of the EU FP7 research programme Models for adaptive forest management (MOTIVE) where researchers from this initiative participate. It is such capacity that enables the reduction of vulnerability by learning and adopting new economic, social or

political approaches to limit risks. Consequently, decision support on how to deal with uncertainty and risk are urgently needed and will be developed in cooperation with existing programmes such as *Future Forests* and the planning programme *Heureca* supported by *MISTRA*. Climate change is expected to give rise to opportunities as well as risks in forestry. In order to seize opportunity (as well as to avoid unfavourable outcomes), knowledge on how to adapt forest management is needed. Opportunities in forestry may arise from increasing growth potential for native and introduced tree species while concurrently epistemic risk arises. Major research efforts are needed to support decision makers on outcome risks, and on how and to what extent forest management can modulate them. In the present initiative research will be focussed on:

- Increasing the basic understanding of establishment and survival of naturally regenerated seedlings and how to combine natural regeneration with planting into new and flexible regeneration methods.
- Models for ingrowth of trees in the continuous cover forest management system.
- Models for the interaction between management in young forest stands and future production and risks.
- Silvicultural systems for flexible, multifunctional forest stands.
- Silvicultural systems for fast growing stands (fertilisation, genetically improved material, tree species, etc) and evaluation of possibilities and risks of whole-tree harvests.
- Decision support tools to develop adaptive strategies for managing forests towards sustainability in a future characterised by change.

Theme 4 - Other renewable plant resources, non-food crops

European agriculture is challenged by the need for increasing its competitiveness and profitability and the necessity for developing a sustainable production. Transportation fuel, chemical feedstocks, lubricants, plastics, synthetic rubbers, and fibers, are only some examples of petroleum based products that are expected to decline in production due to limited resources and environmental concern. Consequently, petroleum needs to be replaced by alternative and sustainable sources of energy and industrial feedstocks. Hence, this creates major new economic opportunities for the green sector. Production of raw materials that can fulfill this role holds great potential. Starch, oil, proteins and fibres are all well-known agricultural raw material and which can be used and further developed to replace petroleum as a feedstock. Plant oils are the products that chemically are most similar to fossil oil and thus have the greatest potential in chemical industry. By use of genetic engineering, the chemical structure of the vegetable oils can be changed such as it can serve as feedstock oil in the chemical industry. The conversion of plant oils into biodiesel is a very simple process with little energy losses whereas half the energy of sugars or starch is lost in the conversion into pure ethanol and this also requires much higher investment costs. Starch accumulated in cereals and tuber producing plants is a highly useful material for technical applications such as barriers in packaging, expanded products and functional components in paper production as well as feedstock for processes directed to other substances such as ethanol.

Optimising individual crops such as cereals and oil crops to serve as platforms for several product streams will add value to the individual crop as well as to the farmer and contribute towards sustainable and efficient use of resources. In addition to the production of plant oil to be used as fuel or feedstock or starch for material application, proteins and/or functional fibres can also be extracted from the same plants and used in plastic and packaging application or for other purposes. Biotechnology can be used to further optimising structures of specific proteins

and/or functional fibres thereby increasing the total usage of a specific crop platform and nano-biotechnology can be used in production of materials for different purposes e.g. through nanofibrillation of fibres.

SLU is aiming to co-ordinate a programme that will generate the scientific basis for re-directing carbon flow in plants to produce sugar, starch, protein, functional fibre or plant oil, all designed to substitute petroleum as alternative and sustainable feedstock. An important component will be the efforts in optimising crop platforms for their resources enabling multiple product streams.

There are major prospects of creating new and innovative research that will build on our present knowledge, but also expanding the research area into important and significant topics for a sustainable society and a changing climate. A prerequisite for a successful outcome of this area is the coordination and gathering of necessary competences and knowledge to accomplish a critical mass. Within the present application, *SLU* therefore will merge and co-ordinate research related to renewable plant resources. The research within this programme will be developed following three directions as stated below, but aimed at growth and expansion by taking in new and innovative ideas and subsequently develop the research.

- Multiple usages of industrial crop platforms for several purposes and end-uses.
- Use of genetic engineering for modifying pathways for production of oil, starch, functional fibres, and proteins in the plant.
- Combining plant breeding, farming systems and biotechnology for production of new industrial crops.

Multiple uses of agricultural crops are already a part in several research projects at *SLU* and in other research environments. The new and innovative part in the present application is *production of several useful biomass products in the same crop* developed by breeding, farming techniques, biotechnology, and product characterisation. New cultivars with tailor-made oil, starch, protein and fibre qualities are expected outcomes. The research team behind the present application possesses unique opportunities for a successful outcome of such an aim. This comes from a thorough research experience and knowledge about plant components such as oil, starch, protein, and fibres combined with an expertise in plant breeding, farming technology, biotechnology, and plant product characterisations. More specifically the aim is to produce

- Wheat with a starch quality optimised for production of ethanol regarding conversion rate and general process input. Furthermore, this cereal should also have a modified protein composition giving the desired hexagonal structure of the proteins when polymerised into plastic packaging material and with fibres taken from the straw and husks with qualities optimised for use in bio-refineries.
- High oil oats with oil qualities suitable for production of bio-diesel or use as chemical feedstock, with protein composition highly useful for packaging materials and with fibres from the straw and husks with qualities optimised for use in bio-refineries
- Crambe with modified specific technical oil qualities, with protein composition usable for packaging materials and with rest-products usable for the bio-refinery industry.
- Sugar beet as a high yield crop for bulk oil or starch production to be used for technical purposes and containing functional fibres for production of composite material.
- Barley with functional fibres for production of hydrocolloids and materials, and with starch qualities suitable for the packaging as well as chemical and pharmaceutical industry.

The use of biotechnology in the development of industrial crops will create plants with desired characters. In the present application, the main interest of using biotechnology is for redesigning biosynthetic pathways so that production of desired products can be changed relative to each other and their chemical structures optimised for various technical use. Systems Biology technologies opens opportunities to radically re-program plant cell metabolism allowing for such as the re-direction of sugar from free sugar or sugar based polymer accumulation to oil accumulation in plant storage organs. Further, the rapid unravelling of gene functions and biochemical pathways allow us now to do advanced modification in the pathways of plant storage products, leading to the efficient accumulation of novel molecules tailor suited for various industrial applications. Cutting-edge technologies will be used in order to develop a toolbox of information and genes important for the rational re-direction of carbon flow in plants creating more energy efficient and environmental friendly bio-products and bio-fuels. Access to optimal model systems is an important component in assembly of the toolbox. We have set up and are using two ideal model system for studying carbon flow and biosynthetic pathways that is nutsedge and poplar. This is also an example of cross-border activity in this application in which techniques and knowledge will move across the programme from trees to other plants and vice versa. Thus, of the mentioned strategies, the change of the pathway will be used to create the oats and barley mentioned above.

A new and innovative idea that will be developed within this application is to use genes from microbes and incorporate them into plants in order to change protein structures favourably for bio-product production in the plant. By this technique it will be possible to create functional proteins for different end-uses directly in plants. Specifically, this technique will be used in the wheat part of the programme as described above.

At *SLU*, we have unique possibilities in Sweden in combining knowledge in plant breeding of new crops and/or new cultivars with specific quality properties for bio-industries. Also, knowledge of sustainable farming systems for the present and coming climate is unique at *SLU*. Thus the combination of research about how industrial multi-crops for bio-industries can be developed by the use of biotechnology, the use of the most suitable plant and farming technologies creates a base and enormous opportunities for sustainable production of renewable plant resources for non-food uses. In the present application, the broad knowledge in plant breeding and sustainable farming at *SLU* will help to create crop plants with biotechnologically improved characters for non-food purposes, transferred to a suitable crop gene background and to a sustainable growing of the crops when they have been developed.

b. Current quality of the research in international comparison

The Faculty of Forest Sciences at *SLU* is, after METLA in Finland, the second largest research organisation in forest science in Europe, and is the organisation that produces the highest number of international scientific papers in forest science in Europe (10% of total).

The MISTRA and forest industry financed *Future Forests* programme is a co-operation between *SLU, UmU,* and *SkogForsk*. The representatives from the forest industry dominate the board of the programme. *Future Forests* was recently established at *SLU* and is the largest forest science related programme ever in Sweden. It is now the strongest centre for dealing with forestry under uncertainty and risk and has international contacts with both organisations like *FAO* and scientist at other universities.

One of the world's strongest research environments for the study of experimental plant research, and especially in the area of experimental tree biology, is Umeå Plant Science Center (*UPSC)*. (See evaluation from VINNOVA – Strong Research Environments in Forest

Biotechnology). The work in the newly established *Berzelii Centre for Forest biotechnology* is performed in close collaboration with the forest and agricultural industrial partners Sveaskog, Bergvik Skog, Holmen Skog, Stora Enso, SweTree Technologies, and Syngenta and has a turnover of more than 200 million SEK.

In relation to the other renewable plant sources, *SLU* has a strong record through coordinating the EC- FP7 project *ICON*. The programme has a turnover of 100 million SEK and has 23 partners. *ICON*'s very concise aim is to develop field-grown plants producing an oil quality with excellent lubrication properties. Through the coordination of *ICON*, direct connections are present with all leading scientists in the world within the research area of biotechnology and vegetable oils and proteins. *SLU* is involved in collaboration with KTH, PackForsk, Lyckeby and other (agro-)industries in Sweden and abroad. *SLU* is an important partner in *Healthgrain* (turnover about 160 million SEK), the major ongoing European cereal research programme with more than 40 partners. *SLU* is also a partner in *RenewFuncBarr* (turnover 30 million SEK), a national programme aiming at developing starch-based films and coatings with good barrier properties as well as coordinating *BarleyFunFood* (turnover so far 12 million SEK) an industry supported programme with the aim of identifying key genes that govern carbon partitioning among different fibre components and starch. The scientists involved in this initiative are highly recognised in the international society.

c. How the potential for development of scientific environment is promoted in the research area

Both universities have ongoing strategic programmes to develop international competitive scientific environments, within centers as well as at different institutions. Centers of excellence such as the *Berzelii Centre for Forest biotechnology* are supported extra from the universities. Platforms like the metabolomic-, proteomic- and microscopy- platforms and the facilities for growing plants, the biotron, climate chambers, and green-house facilities as well as field experiments are supported by extra money from the faculties. The universities strongly support applications of expensive equipment.

SLU and its partners provide an organisational structure for this initiative which has proven to be effective for other centres of excellence that we are hosting. The initiative will get support from *SLU* and *UmU*, in terms of *i*) organisational structure, *ii*) administrative support, *iii*) financial support, and i*v*) support to the tenure track programme. The universities not only offers, but encourage all of the researchers to take part in training programmes in leadership, project management, entrepreneurship, and innovation. The Dean of the faculty will coordinate the leadership of the initiative and meetings with the Vice Chancellors will also be held on a regular basis. This comprehensive support for development of the initiative will be one essential part for the co-ordination and for the success of the initiative.

Recruitment and employment of researchers are strategically important issues for the universities. The universities will therefore co-fund this initiative with resources that enable international recruitment and international cooperation. Both *SLU* and *UmU* are actively involved in recruitment of professors and re-allocating resources to new positions in strategic areas. The two universities are also supportive in recruitment of younger researchers by special strategic grants. The tenure track system at *SLU* and the corresponding special recruitment system at *UmU* helps the environments to give younger talented researchers a possibility to develop their skills. *UmU* has developed a special career programme for female researchers and women from *SLU* can participate in this programme. Extra money such as this initiative will also be set aside for international visitors, guest professors, and international collaboration. EU-offices at both universities help the scientists to apply for competitive grants. All large Centers

and programmes at the universities have international advisory boards with top scientists from abroad, to promote quality and to increase the international contacts.

This initiative will give ***added value*** to the above described programmes and the existing research groups. The added values that are prioritised in this initiative to;

- create new long-term large field experiments that address questions that focus on tree responses to climate change and responses to different land use changes and the consequences for soils and watersheds. The field experiments are platforms where scientists from different disciplines will meat and jointly focus on testing hypotheses, models and ideas,
- create a closer collaboration between molecular plant genetics and quantitative plant genetics to increase the possibilities for a establishing an internationally leading group in tree genetics (and tree/plant breeding) that will be well equipped both from technical platforms and informative databases to be instrumental for questions regarding plant genetics in the future,
- create, develop and support common technical platforms that can be used to link together different disciplines and research areas in this application. Examples are large scale sequencing and genomics technologies that can bring together ecologists, geneticists, tree breeders and plant physiologists, and metabolomic engineering of non-food crops, as well as for tree breeding, developmental biology, and tree physiology,
- create a closer collaboration between researchers specialised in trees and other plants and to perform interdisciplinary research especially in plant carbon and nitrogen metabolism to understand metabolic pathways and the possibilities that exist to utilise knowledge to explore the full potential of allocation of resources created by the primary production from photosynthesis,
- create a production potential for several useful biomass products in the same crop developed by breeding, farming techniques, biotechnology and product characterisation,
- create an internationally leading and interesting research environment that attracts collaborators from all over the world,
- create possibilities for PhD students and younger researchers to learn and develop their skills in an scientific open, creative, and collaborative environment that strives to be at the forefront of science.

d. Career opportunities for young researchers via the initiative

SLU has recently implemented a number of incentives. Examples of such incentives are *i)* allocation of internal research funding directed towards research groups that have a track record of high productivity (in terms of peer-reviewed publications, PhDs educated, and external grants attracted), *ii)* internal research funds for supporting specific strategic research areas, *iii)* creation of a limited number of internal competitive "grants for excellence" (two million SEK per year for 6 years) given to individual professors and research group leaders, *iv)* as the first university in Sweden, *SLU* has launched a **"***tenure track***" s**ystem that resembles the system used in universities in the U.S. The tenure track system is primarily a strategic recruitment of young scientists. The stepwise development contains post-doc positions (two years with good possibilities to spend one year at another university or research organisation abroad), assistant professor positions (four years), docent positions (senior lecturers) combined with tenure, and professor positions. The two last steps are combined with part of the salary guaranteed from the university. Every department has beside this a guarantee of at least one

permanent assistant professor position. Hence possibilities for future research positions for promising young researchers are very good within *SLU*. At *UmU* there are two programmes the Young Researchers Award a unique grant with the aim to identify the foremost researchers at an early phase in their careers and support them financially during two years, and a tenure track system for researchers within centres of excellence.

As a means of ensuring that this programme will attract the very best young researchers, sufficient funds will be allocated. The critical bottle-neck with regard to an academic career in the Swedish university system is generally perceived to be the post-doc level. Hence, priority will be given to raising young scientist positions, both aimed at sending Swedish postgraduates abroad and at recruiting PhDs educated elsewhere. Special care will be taken to ensure that an international research environment is fostered within the programme.

e. How the area is prioritised in the applicants' activities

The domain of research (and education) for *SLU* is summarised in the following mission statement, as set out by the Government: "*SLU* develops the understanding and suitable use of biological natural resources". Thus, the primary production of plant raw material, as well as the utilisation of plant material, is based on scientific knowledge that is sustainable for tomorrow.

Therefore, strategic input in terms of money has recently been decided for research activities within prioritised areas. Examples of such implementations are the strategic support for the research groups of Professor Sten Stymne, Professor Sara von Arnold, Professor Peter Högberg, Professor Torgny Näsholm, Professor Rishikesh Bhalerao, Professor David Wardle and the support for the *Berzelii centre for Forest Biotechnology* and the *Future Forests* programmes. Such strategic support creates opportunities for involved groups to concentrate on research, international contacts and innovative products instead of other duties.

The prioritisation of infrastructure is described below. The support to expensive equipment is often discussed at the universities and a strategic plan is currently worked out at *SLU*.

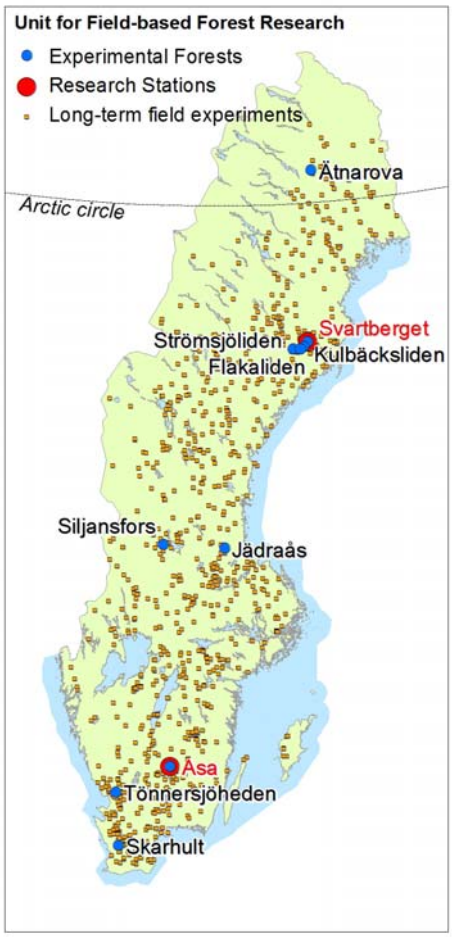
f. Infrastructure

The infrastructure at *SLU* is *excellent*. It consist of the following parts

- research parks and ongoing long-term field experiments and experimental plots all over the country both for forest and agricultural research
- background data from long-term monitoring of forests, landscapes, biodiversity, etc., and responsibility for the National Forest Inventory (since 1923)
- excellent facilities for experimental studies of plants with well equipped laboratories, biotron, climate chambers, growth cabinets, green-houses and field plots
- biotechnological platforms, in genomics, metabolomics, proteomics, cell biology, bio-imaging, trans-gene technology and bioinformatics/computational Life Science Cluster (*CLIC*). These platforms are very well equipped with instruments, data-bases and have professional staff to carry out the technical research.
- national responsibility for the platform in metabolomics.

No other university in Sweden has this type of infrastructure that will allow direct access to experimental plots both in forests and at agricultural land. No other university in Sweden is as well equipped with biotron, climate-chambers and greenhouse facilities or laboratories with well functioning technical platforms.

The long-term experiments are of great importance. For example the Flakaliden experiment, dealing with impacts climate change and nutrient and carbon issues, has generated 40 PhD theses and more than 200 scientific papers in international journals. Of special interest is the newly established "production park" Strömsjöliden, in northern Sweden. Strömsjöliden is a 2980 hectares forested area, owned by Sveaskog AB, where different aspects of the forest, biodiversity, and water related questions will be addressed in relation to new innovative silvicultural approaches to achieve a sustainable provision of forest products and ecosystem services. In the south of Sweden such a "park" is also currently in progress to be created through agreements with Sveaskog AB.



Map showing the location and name of field stations and experimental forests (larger symbols) within the Faculty of Forest Sciences. Smaller dots indicate the location of long-term forest experiments.

These new research parks will provide the opportunity to establish large-scale manipulation experiments, and could be very suitable to host some of the sites within the new ICOS network for monitoring greenhouse gasses, which is under development.

One of the platforms is currently a *national facility for metabolomics*, established at *UPSC* via funding from Wallenberg Consortium North (*WCN*) to analyse samples from both plants and animals (www.upsc.se/metabolomics.htm). Here mass spectrometry (LC- and GC-MS) based methods for metabolome analysis of tissues and fluids have been developed and used in different projects. The facility uses high throughput data processing and chemometric analysis for data evaluation. A metabolomics database has been created at *UPSC* with the main focus on building mass spectra libraries from extracts of *Arabidopsis, Populus* and other plant

species and biological tissues and fluids of interest, making possible identification of unknown metabolites. We are not applying for any infrastructure funding for the metabolomics platform, even if the platform still is regarded as a national facility.

g. Need for expensive equipment

In this application we have not included major investment in expensive equipment. Such investments need much larger support, a small sum for improving some of the existing infrastructures are indicated in the budget.

h. How research will be linked to advanced education and research training

Research is very well coupled to education at the universities. All researchers are also teachers. The education at the universities has to be coupled to research to maintain a high standard. In Umeå is the *Master Programme - Plant and Forest Biotechnology* run jointly by two universities.

PhD research schools are already present in part of the area of the present application. The existing PhD schools in *Forest Management - Forest Technology* (FIRST, together with Finnish universities) and in *Forest Genetics and Plant Breeding* (http:// resschool.slu.se), plus other students are coupled to this initiative. A new research school for PhD students in the area of other renewable plant resources is included in the budget.

i. How gender equality and diversity are taken into consideration in the proposed initiative

The universities *aim to be inclusive* and consequently universities have gender equality and diversity policies and programmes, both universities also live up to the requirements of discrimination legislation. *UmU* and *SLU* have therefore started a special programme for academic career for young female researchers, which *has now run four consecutive years and is planned to continue*. Coaching programmes has been established in *UmU* called “Curious about leadership”. The *Berzelii Centre* have a special programme for foreign researchers to introduce them to Sweden and to the work. These initiatives are adopted by other institutions at the faculties. *SLU* is actively working on gender and equality issues, and is launching new initiatives that start already during the PhD period. Mandatory gender equality plans are drawn up at central, faculty and department levels. The Universities have management groups for gender equality issues, and gender equality officers provide individual employees/students and management at all levels with information, advice and training in gender equality issues. Extra resources of 4.5 million SEK per year have been allocated to increase the proportion of women at senior positions. Gender equality and diversity will be addressed in this programme, by the special recruitment programme. The universities will co-finance the initiative and have strategic plans for these issues.

The *strategy for internationalisation* that exist at the university will give better chances for young scientists to spend time abroad at leading laboratories.

3. Strategic importance

a. Why and in what way the research area is or can become of strategic importance for the business sector and society

Forestry is of fundamental importance for Swedish economy. Sweden is the second largest exporter in the world of pulp, paper and sawn wood. Almost 12% of the export value from Swedish industry emerges from the forest sector (127.5 billion SEK in 2007). Forestry forms the base for the renewable energy in Sweden. Out of the total production of 112 TWh based on renewable bio-resources, 105 TWh has its origin in the forests, which correspond to more than 35 % of the total energy "consumption" in Sweden. Swedish forestry and its products reduce carbon dioxide emissions into the atmosphere by 60 million tonnes per year. This is of the same magnitude as the entire Swedish emissions of carbon dioxide. The climate benefit of Swedish forestry and the substitution for non-renewable material is therefore very significant. The global demand for wood products (e.g., energy, paper, and pulp) is growing at around 2% annually, and Sweden is one of the three leading export countries in the world of wood based material.

The significance of forestry in the country could be even greater with an increase in forest growth coupled to innovative high value industrial products from renewable material. A research programme which increases forest growth provides more renewable raw material which can substitute energy-demanding products and therefore reduce carbon dioxide emissions. It can also form the base for industrial development of new products. Silvicultural measures that take into account risks, ecological services, and demand for increased biodiversity result in higher mean carbon stocks in the forest and higher environmental values compared with a forest cultivated with lower growth targets. There is not *a priori* contradiction between production and sustainable use of forests; on the contrary a sustainable management system can be beneficial both for climate and provision of ecological services and biodiversity. Forests and natural areas also play other very important roles for the Swedish population. Hunting, fishing, recreational, and aesthetic values are highly appreciated and nature tourism and health recreation in beautiful landscapes are increasing. Therefore, an increased production must take into account the sustainable management of forest resources, and beside *SLU* and its partners no other universities can provide the broad knowledge base that is needed.

The research on non-food crops, described in this application, is with properties suitable for end-uses in industrial applications such as technical oils for use as feedstock, ethanol and biodiesel for use as liquid fuels, fibers for material production, and protein and starch polymers for use in the production of plastics and other materials. A successful development of bio-based feedstock for global markets is critically dependent on the effectiveness and cost competitiveness of the chosen production strategies. The choice of a non-food crop platform for the feedstock production is then of great significance for a successful transition from a petroleum-based economy towards a sustainable bio-based economy. *SLU* is the only Swedish university that combines crop cultivation, plant breeding, and biotechnology with comprehensive expertise in biodiversity and environmental research as well as material science. Knowledge areas of fundamental importance are present in the field of development and cultivation of crops for non-food purposes. It should be noted that green biotechnology as well as the production of non-food crops is already in place and ongoing at several departments at *SLU* and *UmU*. The green biotechnology is used for different purposes, as

development of specific types of plants and crops that can be used directly for production of technical oils with certain qualities and work towards modifying pathways within the plants, such as re-allocation carbon flow from starch into oil accumulation. Using non-food crops for production of the next generation of feedstock is an increasingly expanding research topic, both in the rest of Europe and even more so in the U.S., where enormous amounts of resources are directed towards development of environmental friendly production of resources for the growing bio-industry. Co-ordination and gathering of research concerning other plant renewable resources for non-food products at *SLU* will lead to increased possibilities for businesses in Sweden to develop new sustainable products for domestic use, but also for export. With new multi-uses of non-food crops for several bio-industry purposes, there is a great potential to increase competitiveness and profitability of Swedish agriculture.

Optimised production of agricultural raw material for use as feedstock in the industry, where each crop is utilised for several purposes, increases the value of both the crop and of the farming business. The renaissance of agriculture as a vital producer of resources for the industry is a most welcome opportunity for especially rural communities to benefit from this development. Since the programme will be funded out of public money it is important to stress that the society in the long run will benefit from this research through an improved quality of life resulting from a more sustainable use of natural resources, an increasing competitiveness and profitability of the agriculture businesses and a bio-based industry. Creation of new, innovative and challenging job opportunities will benefit not only the rural community, but also other parts of food and non-food production chains as well as consumers in Europe and globally. In the long-term this will add the competitiveness of Sweden and contribute to the global challenge of change to a sustainable society built on renewable resources.

A Nordic public private partnership between Nordic plant breeding companies and universities on collaboration in plant breeding research and other pre-commercial pre-breeding efforts is about to be established as a result of these initiatives. A strong Swedish research environment will have very good possibilities to become heavily engaged in this Nordic partnership to the benefit of the growth of Swedish industrial and other non-food uses of crops. It can be emphasised that *SLU* is the only Swedish university where plant breeding research is represented.

b. Strategies and plans form implementation of research results

We want to initiate a change process where actions are taken based on the results generated in this initiative and in order to achieve this, communication of results are of course of utmost importance. Furthermore, since we want our research to be based on questions that are currently asked by practitioners and among other stakeholders in Swedish forestry and agriculture, communication must be directed both ways. Thus, the communication process must be continuous and iterative and include exchange between science and practice.

Important stakeholders for this initiative are among others; industry, managers, international, national, and regional governmental authorities, national and international policymakers, municipalities, other business, NGOs, and other national and international research groups and individuals working with related issues. Specific communication activities will be undertaken in order to reach each specific group of stakeholders.

The choice of which channels and activities to be used depends on the complexity of the issue. There is no "one size fits all" formula, but there are a number of tools and techniques that can be applied to suit a given situation. A short description of the various outreach tools that are already available or planned to be developed at the Faculty of Forest Sciences and our partners is given below. We recognise that timing as crucial and will schedule many of the activities to coincide with important national and international meetings and political decisions in order to raise interest and make as large impact as possible.

An implementation plan will be developed and based on direct co-operation and regular information/communication activities between academia and industry. Most important is the co-operative work between partners. These networks already exist and represent a solid base to start from. Workshops and excursions on specific topics as well as demonstration of research results and field tests will be arranged by the steering committee. Seminars where subject areas are discussed in depth and where international expertise is invited will be arranged. The capacity for arranging such activities in a professional way exists within this initiative.

Excursions and seminars

Several seminars and excursions aimed at dissemination of research results are organised each year by *SLU* and its partners (*UmU* and *SkogForsk*). For example, *SkogForsk* organises large seminars (Rationaliseringskonferenser) every second year that are attended by thousands of forest managers. *SLU* organises one large seminar each year (höstkonferens) that has several hundred forest managers and forest decision makers in the audience. Furthermore, the Faculty of Forest Sciences at *SLU* and *SkogForsk* arrange by themselves and jointly more than 30 large excursions each year. In addition to our own excursions and seminars researchers from this programme will participate in excursions and seminars that are arranged by other organisations such as the Board of Forestry, forest owner associations or other forest organisations.

Similar meetings take place with the non-food industry and companies producing high value products from agriculture: Each year the Faculty of Landscape Architecture, Horticulture and Agricultural Sciences arranges meetings with the public (Alnarpsdagarna) and meetings with industrial partners. In Alnarp the well established partnership between stakeholders and scientists (Partnerskap Alnarp) also plays a vital role for communication of research results and for discussions about research priorities.

International conferences and publication in international peer-reviewed journals

By default, all research results are published in international peer-reviewed journals that have high impact factors. It is an important part of the research process to have the research results controlled and validated by the international research community. The aim is to have all results published in high-ranked journals, which gives high visibility in the international research community within the field.

With the same purpose as publication in scientific journals, attending international conferences within the specific fields of research is an important task for researchers in this research programme. In addition, at least two international workshops/conferences will be arranged within this research initiative during the coming five years.

Publication in popular scientific journals
All research results that are published in scientific journals will also be summarised in popular form in Swedish. The research projects and research results will also be summarised at the web-pages of *SLU* - Faculty of Forest Sciences, *SkogForsk,* and *UmU*.

Media
Interactions with the media are an important responsibility, and we do invest in an active media work. *SLU* and its partners have well organised media groups with scientific journalists among their staff. This work includes sending press releases, give exclusive interviews and open press conferences, and writing debate articles. Furthermore, research and research results will be published in a popular form at the web pages of *SLU, UmU,* and *Skogforsk*

Decision support tools
Many of the results that are obtained in this research will be implemented in decision support tools. To secure implementation of research results decision support tools are important. Today forest management is done by fewer people who are managing an increasing area per person. However, the new generation of forest managers are used to computer aided help-tools. Such tools have been developed in the EU programme *EFORWOOD*, coordinated by *SkogForsk*, and in the planning programme *Heureca* at *SLU,* which will be further developed within *Future Forests*. These tools will be instrumental in the communication of results and development and will be introduced and presented at regular intervals in meetings, excursions and workshops with industrial partners. Examples of decision support tools that will be developed are:

- Decision support tool to decrease the negative effect of root-rot and wind-throw
- Decision support tool for choice of regeneration treatments
- Decision support tool for choice of sites for fertilisation in young and mature stands of Scots pine, Norway spruce, and lodgepole pine.
- Decision support tool for choice of tree species and provenances with consideration of climate change
- Recommendations for management of mixed species and uneven aged stands
- Recommendations for choice of sites for continuous cover forestry

Patents
According to Swedish law University researchers own all the rights to their own inventions, irrespective of how the work was financed. This law, the so called “teachers exemption”, means that the Universities have no rights to the intellectual property developed by its scientists. However, although this law constitutes an opportunity for the researcher, it is generally considered as a problem for the efficiency of commercialisation since most scientists do not have the time or money to pursue the patenting of their own inventions. The universities have tried to support their researchers by forming various holding companies that can assist in patenting in exchange for partial ownership of the patent. Thus, as all other universities in Sweden, *UmU* and *SLU* own holding companies (www.sluholding.se).

A unique and powerful strategy to implement and commercially develop inventions made in basic research in this field is already created. The model is based on three different types of actors, the academy with its scientists, and two different kinds of companies, here exemplified

with SweTree Technologies (*STT*) and Woodheads AB. PIs at *UPSC* and the Royal Institute of Technology in Stockholm form "Woodheads AB". This company is the largest owner (about 1/3) of *STT* (www.swetree.com). Three of Europe's largest forest owners, Sveaskog Förvaltning AB, Bergvik Skog AB and Holmen Skog AB, and the second largest forest company in the world, Stora Enso, hold shares in the company. Also the Holding companies of *UmU, SLU* and the Royal Institute of Technology (*KTH*) hold shares in *STT*. The company has filed over 90 patent applications and has already commercialised several of its inventions.

When a PI joins Woodheads (through a purchase of shares in the company) he/she signs an agreement with *STT* giving *STT* a *first right of refusal* to all the PI's intellectual property in the area of "plant and forest biotechnology including forest industrial chemistry" with a pre-determined fee structure for revenue to the PI. In return, *STT* takes all the costs for evaluating the patentability and commercial potential of the invention. If *STT* decides to file a patent application, the company takes all costs for this. The PI gets a fee for helping *STT* to write the patent application and a fixed percentage of the revenue from licensing, royalties and sales. Also the PI's host university department gets a fixed revenue (currently 25% of the PI's revenue).

STT has a highly professional patent organisation which has acquired a substantial expertise in the filing of forest biotechnology patent applications, including a large network of connections to various international biotech, agriculture and forestry companies. When a patent application is filed, *STT* forms a patent project group focussed on developing the commercial value of the patent application through proof-of-concept and proof-of-principle work. This work is sometimes performed within the original research group, which for this work can get monetary support from the company. For the more applied projects, further development takes place using *STT* personnel. Decisions regarding patenting and project developments are taken with the help of a scientific advisory board consisting of six *UPSC* and *KTH* PIs with forest biotechnology and chemistry experience. This approach has proven to be highly successful.

c. Capacity and support for implementation

As described above, the capacity and support for implementation is already well developed. In addition, both *SLU* and *UmU* have activities in their holding companies that will support the implementation. Both universities are represented in the Board of Uminova Innovation

d. Engagement and participation of the business sector, industrial research institutes, and other community organisations in problem formulation and implementation of research results when it's relevant to the strategic research area.

This application has an extremely broad and strong support from industry. Furthermore, *SkogForsk,* owned by Forest companies, is directly involved in the initiative. *SkogForsk* has an ongoing international cooperation first with forest institutes in Europe, but also with Institutes in USA and Australia. They are also co-ordinating the EU framework programme *Novel Tree* with 12 other European partners.

Some of the more important forest companies that directly support the initiative are*: Holmen skog, Stora Enso, SCA, Södra, Bergvik, Sveaskog, Skogsindustrierna, Skogsägar-föreningarna, and the Swedish farmers union (LRF- skogsägarna).

Among the support from funding agencies to the universities can be mentioned MISTRA, VINNOVA, SSF, VR, FORMAS, The Swedish National Energy Administration (STEM), Knut och Alice Wallenbergs stiftelse, Kempestiftelserna, and EU's 7th FP.

In the *Berzelii Centre* and *Future Forests* industry representatives are in majority in the Boards and take a very active part in formulation of research questions, active research, and implementation.

**Because of the very late notification from VINNOVA (Friday 7th March) about the requirement of support letters we can only enclose a limited number in part 6 - research constellation. If needed, more letters of support can be sent on request.*

4 Collaboration with other universities, corporations, industrial research institutes, public services and other community organisations

4 a. National and international partners to be involved in collaboration.

SLU is the main applicant and *UmU* is the national partner.
For the nature of the direct collaboration among the three partners *SLU, UmU and SkogForsk*, see below.

Swedish University of Agricultural Sciences (SLU)
The domain of research (and education) for SLU is summarised in the following mission statement, as set out by the Government: ”SLU develops the understanding and suitable use of biological natural resources”. Thus, the primary production of plant raw material, as well as the utilisation of plant material, is based on scientific knowledge that is sustainable for tomorrow. SLU is Sweden’s main centre for research and higher education in forestry, agriculture and natural resource management. Research activities cover fundamental research in e.g., molecular biology, genetics, physiology, ecology, and soil science, as well as problem-oriented research, e.g. forest resource management, forest products, and economics.

- *SLU* has a unique profile with a broad sphere of high-quality activities in areas of great importance and relevance to society and industry.

- *SLU* has four faculties that are located at four main campuses. *SLU* is a research-oriented university with some 215 professors – more than 20% women - and a total annual turnover of about MSEK 2,500, out of which more than 70% goes to research and postgraduate education. About 50% of the research budget is funded from external sources and more than 100 students receive their PhD every year.

- *SLU* is the sole Swedish academic player in many areas and has the national responsibility for several unique professional educational programmes, including those for agronomists, foresters. *SLU* has about 3,500 full-time undergraduate students and due to the high staffing ratio, with an average of 1.4 students per teacher, SLU can offer direct contact between students and teachers/ researchers.

- *SLU* research spans a broad spectrum: from genetic resources to entire ecosystems; from natural sciences to social sciences; from basic to applied research. Research on plant biology encompasses areas ranging from cell and molecular biology to the ecophysiology of whole plants. *UPSC* and the *Berzelii Centre for Forest biotechnology*, *FuncFibre* are national centers of excellence. Plant breeding and plant biotechnology is particularly strong regarding the use of plants for non-food products. Research on the structure and function of forest ecosystems, management of forests and work on the interactions among plants, microbes, and the soil is regarded as world class, as is research on carbon balance and the interactions between carbon cycles and nitrogen cycles. The Faculty of Forest Sciences has high class remote sensing researchers and laboratories and internationallay well known scientists in biostochastics and natural resource economy. The infrastructure for research is extremly strong and quite unique. Within environmental analysis and soil science, databases and long time series are used to study the effects of climate change on

carbon storage in the soil, on the leakage of humus, and the uptake and release of greenhouse gases. The Faculty of Forest sciences is involved in world-leading research in forest ecology and on the interactions between plants and mycorrhiza.

- In addition to basic research, SLU supports industry, society and government with problem-oriented activities and information. Collaboration with the forest sector has a strong tradition at *SLU* and is regarded as a cornerstone for both research and education. *SLU* is the only Swedish university that acts as a national data host for environmental monitoring and assessment programmes, such as the National Forest Inventory (*NFI*) and the Forest Soil Inventory (*MI*). Environmental monitoring contributes to the official Swedish statistics about changes in the environment and is the basis for evaluating progress towards the national goals for environmental quality. Researchers at *SLU* benefit from the easy access to unique sets of long-term data, and a closer integration between research and environmental monitoring is currently being developed.

- SLU also has a special task in *environmental monitoring and assessment*, which makes the university a key player in interpreting and understanding changes such as those that may result from a warmer climate. Forest ecosystem data are provided by the *National Forest Inventory* (*NFI*), the *Soil Survey*, the *Swedish Species Information Centre*, and other environmental monitoring and assessment programmes at *SLU*. Wall-to-wall forest information on individual holdings and forest landscapes are provided by combinations of field survey *(NFI*) and remote sensing techniques for the whole of Sweden (kNN Sweden, raster elements 25 m^2) from the *SLU* Remote Sensing Laboratory.

- National as well as international cooperation with universities and excellent research environments is extensive and SLU cooperates with institutions in more than 120 countries. SLU offers several long-term international diploma courses, MSc and PhD-programmes. SLU is a member of several high-quality networks of Life-Science universities in Europe, such as Euro League, NOVA and BOVA and has a long and fruitful cooperation with developing countries. The development work also includes a number of missions for international and global organizations, such as EU, FAO the World Bank.

Umeå University (UmU)

- *UmU* is a comprehensive university with four faculties, more than 27 000 students, and 4000 employees. The university has 300 full professors and 1 200 doctorates. The annual turnover of is 3.2 billion SEK, of which 1.8 billion SEK is for research and postgraduate education.

- *UmU* has during the period 2003-2007 published 8 400 peer reviewed paper with an average citation rate of nine citations per paper. A ranking of European universities, based on a bibliometric study of the period 2003-2007 published by the Leiden group (CWTS), shows that *UmU* has a crown index value of 1.24 (CPP/FCSm). This positions Umeå University as one of the top three universities in Sweden, and one of the top six in Scandinavia (http://www.cwts.nl/ranking/top250_green_lst.html).

- *UmU* is also one of the leading universities in teaching in Sweden. We offer 150 programmes on under-graduate and graduate levels and in total 2000 courses each year.

Our high quality is verified by extensive evaluations from the Swedish National Agency for Higher Education.

- Four years ago *UmU* selected, based on bibliometric analysis and peer review, twelve strong research areas. Eight of the twelve has since then received external strategic support such as Linné, Berzelius, FAS, FORMAS, SSF-centre of excellence and industrial grant of more than 720 M SEK. *UmU* has so far supported these research groups with 164 M SEK in new resources. For the period 2010 to 2014 the board of our University has allocated 150 MSEK to a selected number of the strong research areas. After external peer review, six to eight areas will receive support to career positions, infrastructure and international guest professors.

- Proven capacity to foster young scientists will be additional criteria to proven excellence. In addition to supporting already established areas of excellence, Umeå University has strong ambitions to support young scientists. A special form of support entitled career grants was launched 2008 where scientists with a PhD not older that 10 years could apply. After external peer review 70 out of 240 applicants received a grant of 2 MSEK (In total 140 MSEK). Hundred million SEK is already allocated in our budget for 2011 when another 50 young scientists will receive career grants.

- UmU is a comprehensive university with nationally as well as internationally competitive researchers within all four faculties. The university continuously works to further strengthen the research and at the same time stimulate new competitive research areas to develop. After extensive analysis, including bibliometric analysis and peer reviewing, twelve research areas were selected and defined as the strong research areas at our university. The programme Forest and other plants is associated to *UPSC*, one of Umeå University's areas of excellence. Based on the quality of the research and future prospects and ambitions it is with strong support and confidence that Umeå University stands behind the proposed programme.

- *UmU* has designated two strategic areas of development seen as having strong potential to evolve into one of our future 'Areas of Excellence' – The Berzelii centre represents one of Umeå University's areas of development, and the area Forest and other plants belong to this category. Based on the quality of the research and future prospects and ambitions it is with strong support and confidence that Umeå University stands behind the proposed programme.

- At *UmU*, research includes theoretical and empirical studies of resource dynamics under uncertainty, climate- and environmental policy, resource conflicts and social change, as well as the effects of governance and awareness-raising mechanisms. *UmU* researchers are involved in large-scale EU, International Polar Year, and national projects with relevance for forest systems, for instance regarding biofuel, adaptation to climate change and cost-benefit analysis. The Faculty for Technology and Natural Sciences has a large number of researchers in relevant areas.

SkogForsk

The Forestry Institute of Sweden, *SkogForsk*, plays a unique and vital role in satisfying the forest sector's needs for operational research and efficient dissemination of new knowledge concerning the sustainable management of forests. *SkogForsk* is supported by the forest sector and the Swedish government through a Framework Programme, financed 50% by the

Swedish government (via Formas) and 50% by the ca 100 forest sector members of *SkogForsk*. Overall, the forestry sector finances about 70% and government or other public funds about 30% of *SkogForsk*'s activities. This has direct implications for the way *SkogForsk* works. The organisation is responsive to the demands from the stakeholders of *SkogForsk* who collectively define *SkogForsk*'s role and the expectations it must meet.

Research areas span forest production including tree breeding, silviculture, conservation of nature and the environment, as well as forest operations including wood utilisation, logging, logistics and forest bio-energy. Through its research efforts Skogforsk supplies an important public good to the forest sector and the Swedish society.

Skogforsk's special areas of excellence of particular relevance to this initiative are: (i) the tree improvement programmes focussing genetic adaptation of tree species to climate change as well as increased growth potential for a sustainable use of the forest resources; (ii) research and development concerning cost effective implementation of policies and certification schemes for ecosystem conservation and promotion of ecosystem services; (iii) development and adaptation of new forest operations and logistic systems to changing soil conditions caused by a potential warmer and more moist climate. The latter includes development of more lenient techniques for harvest and transport on non-frozen soils and roads.

Through its research efforts *SkogForsk* supplies an important public good to the forest sector and the Swedish society. There are two features of the research efforts done by *SkogForsk* that are of particular relevance to *Future Forests*. One is tree improvement programmes being the most prominent manifestation of the overall public-good functions. The other is the highly skilled and efficient work with dissemination and extension that enables *SkogForsk* to make a large contribution to the efficiency and sustainability of the Swedish forest sector and hence society as such. The ambitions of the *Future Forests* programme are fully in line with the vision and goals of *SkogForsk*, and this research proposal will impact the *SkogForsk* Framework Programme currently being drafted for the period 2009-2012.

No international partner is directly involved. Indirectly (through collaborations, although not financed by the present application) a number of other universities, corporations, and industrial research institutes are involved in Sweden and the rest of the world. Such collaborations are already present in a range of ongoing projects such as e.g. the ICON (23 partners from universities, corporations, and industrial research institutes), different Formas, Vinnova and VR including collaboration e.g. with KTH and MaxLab in Lund, but also by newly formulated research collaborations, fitting well into the theme of this application although not granted yet, as for the collaboration with LU concerning use of microbes for biotechnological determination of protein structures.

There are a number of *international collaborators* that inevitably will help to develop the research described in this programme. All scientists involved in this initiative have their own extensive networks with colleagues all over the world. As can be expected from ongoing research these initiatives will strengthen in the future. There are also a number of possibilities to search for money for exchange between researchers. Normal student and staff exchange programmes within the 7th Framework programme is already utilised by researchers in this initiative. Also, there already exist written agreements with several research organisations. Partners are also mentioned in attached CVs. A few examples where written agreements exist are given here. INRA- Versailles a major European site for research in plant biology and

agronomy, and strong in biotechnology. INRA, Department of Ecology of Forests, Grassland and Freshwater located in Nancy, Bordeaux and Orléans where the forest research is strong in Nancy and Bordeaux and the agronomy research in other places in France. University of British Columbia- UBC in Vancouver in Canada in the area of Forestry and they also have part of the large functional genomics programme "Genome Canada". In this area cooperation also exist with plant Science Center in Yokohama, Japan and the Max Plank Institute, Golm in Germany, and Copenhagen University , in Denmark. Exchange on regular basis and with agreements exist in forest science with North Carolina State University (NCSU), Chinese Academy of Forestry (CAF).

The cooperation with Nordic Universities e.g. in Joensuu and Helsinki and with the Finnish Forest Institute, METLA, and the Danish Institute Skov og landskab is strong.

Researchers in this initiative also have a role in international organisations as EFI (European Forest Institute) and IUFRO (the International Union of Forest Research).

As mentioned above SLU and its partners have a number of other networks. *SLU* has an ongoing plan to sign agreements with specific universities. These will be selected based on performance in different fields. One such European group already exist in the initiative of the so called "*Euroleague*" a small group of universities in Europe involved in agricultural sciences where *SLU* is one partner.

4 b. Forms and conditions for collaborating between collaborating partners

An agreement will be made between Vice-Chancellors of the universities. In the same way *SkogsForsk*, via its CEO will sign a special agreement with the universities. Such agreement already exists due to earlier cooperation, i.e. *Future Forest*.

This new agreement is centered around a strengthening of the academic competence in forest genetics and tree breeding with a new higher position as professor and new positions as post-docs and assistant professors. Funding for a professor in tree breeding will be guaranteed, if this initiative is supported, both from the programme and from the universities.

4 c. Desired distribution of funds between the universities applying for grants via the proposed initiative

The universities are partners. *SLU* cover the majority of the initiative and *SLU* has 80% and *UmU* 20% of the total grant. The collaboration with *SkogForsk* will be supported from the grant to the universities for a new position and for direct costs.

4 d. how collaboration is expected to affect the development of the research environment.

Excellent researcher can be found in many types of organizations, but a well functioning organization will have much better possibilities to help researchers to fulfill their potential and also to create an open, communicating and vibrant and interesting scientific setting that attract young researchers and guest researchers. Therefore this initiative is well aware that an organizational plan must be at hand.

The partners in this initiative have very good experience of building research centers, task forces and technical platforms and these experiences will help this initiative to create a good organization built up of research groups with the same interest and where PIs, post-docs , associate professors, PhD students and technical staff work together. The common technical platforms are important since they attract researchers with similar interests working on different research questions. The collaboration at the technical platform increases chances of finding common interests and developing new ideas. The distance between Umeå and Alnarp can of course be seen as an obstacle and therefore organized meetings and work-shops must be well planned and an integrated part of the cooperation.

Already today the international collaboration strengthens the possibilities for focused research. Increased funding will be used to create added strength to this collaboration and also to increase the international network, as indicated in the budget. The excellent infrastructure in this initiative also contribute to attract collaborators. Both the field facilities and possibilities to do large scale experiments and the technical platforms are attractive instruments for international collaborators and for testing new ideas and designing new research concepts.

International scientist participate on a regular basis with the researchers involved in this initiative in PhD courses, meetings discussions and in research and testing ideas in the field or in the laboratories. This collaboration will increase with a better funding of the research and help to create a research environment of high international standard.

5. Budget

Vinnova or the Government has not given any indication of division within the area of Sustainable Use of Natural Resources. We indicate below what we propose as an allocation for ***Forests and other plants***, between years. All figures are in MSEK.

The amount allocated to *SkogForsk* (part from both universities) will be an investment in forest genetics as part of the new initiative to create a world-leading collaborative group in plant/tree genetics and breeding.

	2010	2011	2012	2013	2014	Total
SLU	**10**	**15**	**29**	**29**	**29**	**112**
UmU	**3**	**4**	**8**	**8**	**8**	**28**

	2010	2011	2012	2013	2014	Total
Younger researchers, post-docs, and associate professors	**4**	**4**	**8**	**8**	**8**	**32**
Guest professors and international collaboration	**3**	**4**	**5**	**5**	**5**	**21**
PhD school	**1**	**4**	**4**	**4**	**4**	**17**
Field experiments/tests	**2**	**2**	**4**	**4**	**4**	**16**
Infrastructure	**0.5**	**1**	**4**	**4**	**4**	**13.5**
Recruitment of senior researchers, "tenure"	**0**	**1**	**7**	**7**	**7**	**22**
Genetics (*SkogForsk*)	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**7.5**
Workshops/seminars/ excursions/conferences	**0.5**	**1**	**1.5**	**1.5**	**1.5**	**5**
Information & communication	**0.5**	**0.5**	**1**	**1**	**1**	**4**
TOTAL	**13**	**19**	**36**	**36**	**36**	**140**

6. The research constellation

Steering group
SLU will be the official host of the programme. The Vice Chancellor appoints the Steering Committee for the programme after consultation with *UmU* and *SkogForsk*. The Committee will be responsible for the programme, and thus for assuring that the programme activities proceed according to plan, as well as for the fulfilment of the programme's goals. Three faculties at *SLU* are involved, and one Faculty at *UmU* and since this is a strategic investment for the future in an important area for the universities and its partners.

The leadership position of the initiative will be given to a dean and vice dean responsible for research. This means that the chairman of the committee - *Forests and other plant resources* will be Prof. Jan-Erik Hällgren, Dean of the Faculty of Forest Sciences and the vice chairperson is Ass Prof. Eva Johansson (vice dean). The steering group will further consist of Prof. Sten Stymne, Prof Torgny Näsholm, Prof. Ove Nilsson. Two persons one from *UmU* and one from *SkogForsk* will be appointed after consultations with *UmU* and *SkogForsk*. The appointed persons from these organisations are Prof. Per Ingvarsson (*UmU*) and Research leader Ola Rosvall (*SkogForsk*).

Theme Responsibility
Theme leaders are selected to cover the themes and are responsible for the overall daily running of the themes in this initiative. Names in **bold** indicate those for which CVs are provided.

- Theme one: Team leader Prof. **Torgny Näsholm**. ***PIs***: Prof. **Peter Högberg,** Prof. Vaughan Hurry, Prof. **Sune Linder**, Assoc. Prof. Annika Nordin
- Theme two: Team leader Prof. **Ove Nilsson**. ***PIs***: Prof. Bengt Andersson, Prof. **Sara von Arnold**, Prof. Caterine Bellini, Prof. Geoffrey Daniel, Prof Ulrika Egersdotter, Assoc. Prof. **Per Ingvarsson**, Prof. **Stefan Jansson**, Assoc. Prof. Karin Ljung, Prof. Thomas Moritz, Research leader Dr. Ola Rosvall, Prof. Björn Sundberg, Assoc. Prof. Hannele Tuominen,
- Theme three: Team leader Prof. Urban Nilsson. ***PIs***: Assoc. Prof. Johan Berg, Assoc. Prof. Kristina Blennow, Ass. Prof. Michael Gundale, Assoc. Prof. Tomas Lundmark, Prof. **Marie-Charlotte Nilsson-Hegethorn,** Prof. David Wardle,
- Theme four: Team leader Assoc. Prof. Eva Johansson. ***PIs***: Prof. Per Åman, Assoc. Prof. **Rishikesh Bhalerao** Prof Chuanxin Sun, Prof. Henrik Eckersten, Prof. Christer Jansson, Prof. Lennart Kenne, Prof. Arnulf Merker, Prof. Erik Steen Jensen, Prof. **Sten Stymne**, Assoc. Prof. Bengt Svennerstedt

The theme leaders will have direct contact with the other leading PIs in the initiative. The chairman and vice chair are responsible for the implementation programme including communication and information activities, conferences and meetings as well as contacts with stakeholders. The committee is responsible for maintaining a high research quality in the programme. A scientific advisory board will therefore be organised by the committee and it will include members also from the industrial sector. The committee is responsible to decide allocation of resources to themes after consulting the advisory board. The Universities are responsible for staff, administration and economical accounts and a correct recruitment of persons.