European Cooperation in the field of Scientific and Technical Research - COST -

Brussels, 22 November 2013

COST 053/13

MEMORANDUM OF UNDERSTANDING

Subject : Memorandum of Understanding for the implementation of a European Concerted Research Action designated as COST Action ES1306: Connecting European connectivity research

Delegations will find attached the Memorandum of Understanding for COST Action ES1306 as approved by the COST Committee of Senior Officials (CSO) at its 188th meeting on 14 November 2013.

MEMORANDUM OF UNDERSTANDING
For the implementation of a European Concerted Research Action designated as

COST Action ES1306
CONNECTING EUROPEAN CONNECTIVITY RESEARCH

The Parties to this Memorandum of Understanding, declaring their common intention to participate in the concerted Action referred to above and described in the technical Annex to the Memorandum, have reached the following understanding:

1. The Action will be carried out in accordance with the provisions of document COST 4114/13 “COST Action Management” and document COST 4112/13 “Rules for Participation in and Implementation of COST Activities” , or in any new document amending or replacing them, the contents of which the Parties are fully aware of.

2. The main objective of the Action is to form an EU-spanning network of Connectivity scientists, to share expertise and develop a consensus on the definition and scientific agenda regarding the emerging field of water and sediment connectivity within Europe (and the diversity of European environments), and to identify potential for synergy with other disciplines and research applications in practise."

3. The economic dimension of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at EUR 92 million in 2013 prices.

4. The Memorandum of Understanding will take effect on being accepted by at least five Parties.

5. The Memorandum of Understanding will remain in force for a period of 4 years, calculated from the date of the first meeting of the Management Committee, unless the duration of the Action is modified according to the provisions of section *2. Changes to a COST Action* in the document COST 4114/13.

A. ABSTRACT AND KEYWORDS

Successful prediction of pathways of storm runoff generation and associated soil erosion is of considerable societal importance, including off-site impacts such as water quality and the provision of related ecosystem services. Recently, the role of connectivity in controlling runoff and erosion has received significant and increasing scientific attention, though in a disparate and uncoordinated way. There is a wealth of experience and expertise in connectivity across Europe that could be harnessed to ensure that the potential already demonstrated in key studies can be more widely fulfilled; to move forward along agreed lines and identify emerging goals, and to benefit from cross-fertilization of ideas from the fields of Hydrology, Soil Science, Geomorphology and Ecology. COST is the appropriate vehicle for funding this activity because it will gather together existing expertise to advance the field of connectivity in a concerted way. The key benefit of this Action will therefore be to establish connectivity as a research paradigm. The Action will then permit transfer of current understanding into useable science, by developing it's conceptual basis and transferring it into a series of monitoring and modelling tools that will provide the platform for indices that will inform holistic management of catchment systems.
Keywords: water and sediment connectivity in diverse environments; coordination and concerted action by defining connectivity indices and cross- fertilization of different disciplines; methodology development for measuring and modelling connectivity; the role of connectivity on sustainable land and water management; the role ecosystems on connectivity of water, sediments, nutrients and biochemical fluxes

B. BACKGROUND

B.1 General background

Water and sediment connectivity has emerged in recent years as a significant conceptual framework for understanding the transfer of surface water and sediment and associated substances through landscapes. Discharge of water and sediment from catchments is not simply the sum of the water and sediment that leaves parts of the catchment, but is the result of processes acting at different scales, e.g. re-infiltrating overland flow, colluvial deposits, biota organization or man-made-structures either retarding or enhancing water and sediment transfer through catchments; spatial pattern and magnitude of the runoff generating rainfall event. All in all, connectivity can be seen as both a driver of hydrological and geomorphic processes within a catchment and as an emergent property of the latter that is caused by these processes and their interaction. As one cause of complexity, it not only governs the output of the catchment system, but also the sensitivity of the system in terms of its reaction to change and the way that change is propagated trough the catchment (both up- and downstream). Unlike in ecology, where species mobility among well-connected habitat patches buffers the effects of habitat destruction or fragmentation, the sensitivity (and vulnerability) of hydro-geomorphic systems increases due to high connectivity. Hence, connectivity is also linked to important issues such as the reaction of natural systems to climate change, to natural hazards associated with water and sediment dynamics, and to the management of water and sediment in river catchments. Of particular significance is the impact of human activity in modifying water and sediment connectivity. Forest roads, tractor wheelings, forest fires and soil compaction at field gates, for example, can considerably enhance connectivity, whereas contour afforestation, vegetation recovery or ploughing can reduce it. A step change in the concept of water and sediment connectivity will achieve the unrealised potential of the concept both in terms of enhancing our understanding of landscape processes and in terms of its implementation as a management tool. A COST Action is the most appropriate and timely way of achieving this step change in the field as it will:

1. Harness the experience and expertise in the emerging field of connectivity the diversity of European environments to move forward from case studies towards more generic, theory-guided, comparable research that will enhance predictive modelling and its use as an effective management tool both in Europe and Worldwide;

2. Streamline and harmonise current concepts and research methodologies; discussion and cooperation among researchers and practitioners from Europe (and beyond) will be a basis for new research, through the cross-fertilization of ideas and approaches from various disciplines, like Hydrology, Geomorphology, Soil Science and Ecology.

3. Encourage and facilitate multi-sectorial collaboration, allowing practitioners and policy makers to benefit, which is a crucial facet for implementation of connectivity as a management tool;

4. Through its planned Activities create a greater awareness of the issues and attract others to be involved and partake in the Action; this particularly addresses Early Stage Researchers, young scientists and practitioners;

5. Encourage other (inter)national agencies toward funding of research projects;

B.2 Current state of knowledge

Although much progress has been made in the understanding of the physical processes that control the flows of matter through the landscape, applying this understanding across a range of scales has long hampered progress. While there has been some work on the connectivity of runoff-producing patches and the channel network, especially in dryland areas, studies on sediment connectivity, and the coupled analysis of both runoff and sediment connectivity, are widely lacking. Over the last decade, the concept of connectivity has received increasing attention to address this scaling problem in hydrology (Bracken and Croke, 2007) and geomorphology where it first appeared as geomorphic (hillslope-channel) coupling (Harvey 1997, 2001, 2002). In the context of sediment budgets, connectivity appears as an emergent property linking the output of hillslope-scale systems to catchment-scale (fluvial) sediment yield (Slaymaker, 2006; Brierley et al., 2006); here, internal sediment dynamics and catchment sediment yield are linked, among others, to the configuration of sediment stores and sinks, and to buffers, barriers and blankets that disconnect sediment cascades (Fryirs, 2013). While in some cases, the conceptualization of connectivity draws on ecological theory, a recent review suggested that a major problem has arisen the differences in definition of the term and concept by hydrologists and geomorphologists (Bracken et al., 2013). Therefore, there is a need to develop general theory of connectivity that is applicable in any environment in order to address the issue of scale. The use of hierarchy theory has proved useful in ecology in looking at such problems (Wu and David, 2002), but has only had limited use in the eco-hydrological literature (Turnbull, in press). The latter also emphasizes the effects of dynamic components such as vegetation, and complexity imposed by changing land uses (Lexartza-Artza and Wainwright, 2011; Mueller et al., 2013). This Action thus identifies the need to integrate theoretical perspectives from a broader range of disciplines such as ecology and from interdisciplinary views such as from complexity theory. The development of technologies for assessing spatio-temporal patterns of environmental parameters has been rapid, and in part the development has facilitated the concepts of connectivity. Distributed methods of instrumentation will increase the availability of this information and enable a more thorough evaluation. Sampling designs for such studies need to be developed coherently with the development of the concepts of connectivity theory. In parallel, modelling techniques for evaluating connectivity have also been advancing. There are distinctions between models that have connectivity "built in" (Jones and Heathwaite, 1997; Lane et al., 2004; McGuire and McDonnell, 2007) and those that allow it to emerge as a function of model behaviour (Lesschen et al., 2009). Much effort has gone into developing indices that can be easily applied (e.g. McRae et al., 2008). Such indices rely, for e.g. on apparent properties of permeability fields in (groundwater) Hydrology (Knudby and Carrera, 2006), and on estimations of effective contributing areas (created from DEMs and derived parameters) in Geomorphology (Fryirs et al., 2007; Borselli et al., 2008). Some efforts were made also to combine hydrological and sediment connectivity (Reid et al., 2007). However, no single technique has emerged as being useful in all catchments (e.g. Ali and Roy, 2010). Some approaches to quantify connectivity are in the state of conceptualization (e.g. Fryirs, 2013) and need further development, for example the use of graphs as models and data structures for describing and analysing hydrological and/or geomorphic systems with different degrees of connectivity (e.g. Gascuel-Odoux et al., 2011; Phillips et al., 2011; Poeppl et al., 2012, Heckmann and Schwanghart, 2013). Bracken et al. (2013) suggested that one problem lies in the need for a better conceptualization of indices, and their underpinning using a broader data and modelling basis. The application of indices thus supports the management of landscapes, and the development of robust, easily applicable indices and/or underlying models, provides a vital tool for environmental managers (e.g. Croke and Hairsine, 2006). The advance of a connectivity-based approach is that it provides the potential for solutions at landscape scales, which are compatible with the implementation of key EU policy directives, such as the Water Framework, Bathing Waters and the future Soils Directive.

B.3 Reasons for the Action

The reason to choose COST to fund this Action is that there are already many projects running and in the process of getting funded by either regional, national, European or third-party funds. As most of the funding bodies and research programmes do not have strong linkages between each other, progress in the field of connectivity has mostly been developing in a parallel manner. In bringing together the experience and expertise of researchers in the emerging field of connectivity, COST will enable the transitions:

- from parallel projects within single disciplines to concerted research within an interdisciplinary framework with strong linkages to practitioners and applied aspects (management of water and sediment in catchments).
- from a plethora of case studies to more generic, comparable research,
- from a multiplicity of definitions, concepts and methodological approaches to coordinated, theory-guided research activity along agreed lines, which will provide both immediate benefit for existing projects and a springboard for the development of future research projects.

The Action does not repeat but complements current European research programmes in its dedicated focus on broadening the understanding of hydrological and sedimentary processes and the impact external factors have on this system. To enable the transfer from science to management tool for society, academic experts, local knowledge and field experts need to be brought together, to facilitate multidisciplinary research, sharing knowledge on best practice and new techniques through networking. In addition, the Action will disseminate our knowledge to society by web-based meetings and publishing results on our website and public media.

B.4 Complementarity with other research programmes

The Action builds partly on the knowledge and network of COST 634 (On - and off site Environmental Impacts of Runoff and Erosion (04-08)) and ES1104 (Arid Lands Restoration and Combat of Desertification (12-2016) and has linkages to several EU funded research projects (FP7: e.g. WETWIN; MyWater; CHANGES; REFRESH; DESIRE; EU regional funds: e.g. AlpineSpace EU project SedAlp; Natural hazards without frontiers; Reconnection Lobau). However, none of these projects include the concept of connectivity and its implications on water and sediment dynamics. Among the partners in our consortium there are many projects related to the focus of this Action that are funded by national funding bodies. Linking results and insights of these projects is essential to move the field forward.

C. OBJECTIVES AND BENEFITS

C.1 Aim

The aim of the Action is to form an EU-spanning network of Connectivity scientists, to share expertise and develop a consensus on the definition and scientific agenda regarding the emerging field of water and sediment connectivity within Europe (and the diversity of European environments), and to identify potential for synergy with other disciplines and research applications in practise.

C.2 Objectives

The Action will investigate connectivity in Earth Science in order to develop the concept so that it may be used to prevent and mitigate societal, economical and biophysical hazards. To achieve this aim, the Action has formulated the following overall objectives:

- The Action will form a network of Earth scientists that is composed of experts in different disciplines of connectivity research, and promote participation of Early Stage Researchers (ESRs). This new core of expertise will allow the Action to **critically evaluate methodologies**, both with regard to theory development and experimental research of connectivity in desk study and workshops.

- The Action and Network will **generate an inventory** of i) different definitions and concepts of connectivity and will organize and report on a discussion to come to a consensus definitions and conceptual framework and ii) applications of different branches of science beyond Earth sciences, to identify potentially valuable connectivity related methodologies and theories through desk studies and workshops, and iii) gaps of knowledge and understanding related with connectivity, and will propose a prioritization for research, and report on this.

- The Action will organize of **workshops, trainings**, and ad hoc **'think tanks'** related with connectivity for **ESRs and PhD** students, either associated directly with the Action and interested parties from outside the Action.

- The Action will **disseminate its deliverables towards scientists** within and outside its own domain by publishing findings in scientific journals and on websites and in open access e-learning tools and traditional communication media.

- The Action will **disseminate its deliverables towards end-users** (managers, farmers, schools, public) of scientific research by publishing on websites, flyers and popular books, with scientific language adapted to these groups.

C.3 How networking within the Action will yield the objectives?

A major problem in launching innovative concepts and methodologies is the initial uncertainty with regard to definitions, often arising from a diversity of disciplinary approaches. Particularly for new integrating concepts, it is often poorly known whether and which parallel developments have occurred in other branches of science and their potential value. For this reason, a network is eminently suited to harmonize the concepts within (e.g. connectivity in Earth sciences) and between disciplines. Whereas much research is being conducted on aspects of connectivity, a general agreement on terminology, advances, and major gaps can be accelerated by a more focused and intensive discussion than one, which evolves in scientific literature. In view of the needed discussion and debate, rather than just ‘reporting’ through workshop contributions, a coordinated structuring as well as a partitioning of tasks in a network are needed to address open questions. The Action will also organise think-tank meetings and short-term scientific meetings at locations where one (or more) of the partners is carrying out their research, to develop the connectivity research further in a more structured and holistic way. Participants of such workshops will bring their fresh view on the case study, while learning methodologies and models can be applied at the site, in a consistent manner across all case study sites. The delivery of these objectives will be assessed initially by focussed publications in each of these areas, and subsequently by the take-up of these advances by practitioners. If successful, the Action will have global significance for advancing and using the connectivity concept which will be of benefit to scientists to understand landscape functioning as well as to practitioners of landscape management.

C.4 Potential impact of the Action

Scientific impact

From the scientific point of view, the cooperation and exchange with researchers from different disciplines will increase the understanding of all aspects of connectivity and strengthen the scientific network. Some of the collaboration was already identified by participants in COST Actions 623 and 634 that focused on soil erosion and land-degradation processes. Networking and preparation of future research proposals and exchange of students/ESRs and senior researchers will enable further interdisciplinary cooperation pushing research forward horizontally and vertically. The horizontal aspect will stress viewing the landscape holistically, so that the Action can understand the links between structure and function via connectivity, in order to understand the processes that drive hydrologic function, sediment dynamics and thus ecosystem state. Vertical advances will be achieved by improving theory, model and data links, by setting up a conceptual framework, e.g. for linking measurements with numerical models and enhancing the dialogue between theory, data collection and model development. Furthermore, runoff prediction and soil-erosion modeling will be improved to develop rigorous and comparable conceptual and methodological approaches for assessing and measuring connectivity. Integrating both the vertical and the horizontal science will help to jointly formulate future research proposals and seek solutions to compelling scientific questions of great relevance to society.

Societal impact:

Successful prediction of hydrologic pathways associated with storm runoff, subsequent soil erosion and sediment fluxes (including onsite and offsite impacts) is of considerable societal importance. It is known that connectivity plays an important role in both environmental problems and the triggering of catastrophic events with major impacts on the economy, and (quality of) life. However, despite the general concern about soil erosion and sediment problems, few mitigation actions are put in practice in an holistic manner, that considers the catchment as a connected unit, in both space and time. Strengthening connectivity-related research can lead to improved quantitative and qualitative management of land and water resources (via improved understanding of water, sediment and associated pollutant sources, pathways and residence times in the landscapes). Consistent development of a suit of connectivity tools will enable practitioners to utilize the concept of connectivity in a meaningful way, to help with landmanagement and the sustainable use and protection of water and soil resources, further minimizing landscape disturbance and damage to infrastructure. Tackling the question of water and sediment connectivity in a quantitative fashion will be critical for maintaining good ecological status of river systems (EU Water Framework Directive, 2000/60/EC) and reducing flood risk (EU Floods Directive, 2007/60/EC) as well as supporting compliance with bathing water legislation (EU Bathing Waters Directive, 2006/7/EC; Thematic Strategy for Soil Protection (COM(2006) 231); Nitrates Directive (91/676/EEC)) and related national legislation and environmental management strategies. The key benefit of the Action will be to transfer a conceptual understanding of connectivity into a piece of useable science, while at the same time strengthening the intellectual basis of the emerging paradigm.

C.5 Target groups/end users

This Action will serve two types of target groups: one target group is the scientific community including education, especially at the MSc and PhD level. This community will benefit especially from the planned website, where a lively forum will be created where students and teachers alike can post questions and answers. Teaching and training materials will also be provided. All documents and materials will be disseminated under appropriate open access/Community Commons conditions to facilitate as wide a use as possible. In broader terms, mathematicians, logistics scientists and consultants will be interested in the outcomes of this Action because of wider relevance to aspects of complexity theory and network theory. The second target group are stakeholders such as farmers, land, water and catchment managers, conservation biologists, river engineers, natural hazards, nature conservation and sustainable agriculture institutes; environmental and mechanical consultants, farmers, city planners and authorities and road-construction companies.

D. SCIENTIFIC PROGRAMME

D.1 Scientific focus

As connectivity research is currently disparate due to the lack of a common theory (WG1), this will be the first point to critically review. In this context, the definition and compilation of shared protocols for measurement methods and data collection (WG2) and subsequent modelling approaches (WG3) are long overdue. The latter WGs, through model building, calibration and validation and will, form the basis for indices WG4) that describe connectivity quantitatively. The Action will stimulate research on such indices by pooling different methodological approaches (sensor networks, remote sensing, digital geomorphometry, field surveys) and experiences. Lastly, the results of these WGs will be converted into applied science by the development of usable tools to enable sustainable land and water management (WG5).

WG1 – Theory development

The first task of this Action is to develop a theoretical basis for the concept of water and sediment connectivity and his interaction with the soils and the biota. This theory will provide a sound basis for quantification and indices of connectivity that will be usable across a diverse range of settings both at different spatial and temporal scales and in different climatic zones. The first task of the Working Group will be to integrate advances from other disciplines (for example landscape ecology and spatial transport planning where the concept of connectivity has been employed, sometimes in quite different ways. Using a framework based upon this learning, the Action will review case studies of water and sediment connectivity from a diversity of European (and global) environments to test the robustness of our theoretical model. From this review our first attempt at a theoretical framework for water and sediment connectivity will merge. The Action will then evaluate this first attempt using focused case studies that test the framework under the most demanding circumstances, specifically the problems of dynamic changes in connectivity in response to events of different magnitude and frequency in a variety of climatic settings. Because of the issues associated with the dynamics of landscape function, we anticipate that water and sediment connectivity cannot be conceived in a deterministic framework but will need to be formulated in a stochastic framework. Accordingly, the final aim of this Working Group will be to develop such a probabilistic approach to conceptualising water and sediment connectivity. A total of five Work Packages (WPs) has been designed based on this working strategy (listed in table 1).

WG2 Measuring Approaches

WG2 will incorporate leading teams of scientists to compare and evaluate standardized protocols for field-based quantitative appraisal of water and sediment transport connectivity at multiple temporal and spatial scales. Additionally, this WG will provide a series of tests data sets that will be available in a hierarchized data pool. This pool will benefit from joint efforts between participants to share existing and new data from research projects across a wide range of scales from experimental plots right up to basin scales. WG2 will develop a Working Strategy which, critically, incorporates two important and developing arenas. The first includes new technology, which will support a paradigm shift in the study of landscape modelling. The emergence of new technology is so unprecedented that it is already rapidly altering the way in which we study the Earth Sciences*: we are witnessing a transition from poor, slow acquisition and fast processing of data; to rich, fast acquisition slow post-processing data sets*. The acquisition of terrain data is a clear example of this shift, being also a key component for this Action. New technology (e.g. Terrestrial Laser Scanning, Structure from Motion photogrammetry) allows the acquisition of unprecedented volumes of structural observations, offering novel opportunities in the study of complex landforms and vegetation structures, and their evolution over multiple spatial and temporal scales. However, these technologies require efficient (and standardized) data-processing protocols to overcome the challenges generated by the enormous data sets and the systematic and random errors associated with data acquisition. Within the context of these challenges, the second arena relates to data processing and uncertainty analysis. This provides a robust way to transform raw data into products and to filter out those data that can be considered noise (not real), leaving those that we can confidently use to characterize the structure and function of the landscape, and to identify consequent processes and responses. A total of four Work Packages (WP) have been designed based on this working strategy (listed in table 1).

WG3 Modelling Connectivity

WG1 will have developed new definitions of connectivity that demonstrate how concepts can be integrated across a range of environmental settings, while WG2 will work within these definitions to provide new datasets that can be used to test them. The aim of WG3 is to integrate the new definitions in existing model frameworks and test them with the new, and, where appropriate, existing datasets. WG3 will incorporate a working strategy that includes model and data benchmarking, using model epistemology and structure; representation and testing of connectivity in models; data structures and compatibility. Three specific objectives have been designed. The first will consider model structures and how they can incorporate the advances proposed in WGs 1 and 2, and will run in conjunction with them, e.g. in their initial workshops. The second will take place after WG2 has provided new testing datasets, and will work in collaboration with this WG to ensure comparability and ease of application of the data in existing structures. The third will carry out an inter-comparison of the results of different models, and will also interpret the results in terms of the provision of indices to inform and support the work of WG4, and consider the implications for the management strategies of WG 5. Three WPs have been designed based on this aim (Table 1).

WG4 Usable Indices for Connectivity

Digital elevation models (DEMs) describe the landscape topography, which is both a product and a driver of the activity of geomorphic processes. In the same way, the connectivity of landscape units with respect to water and sediment fluxes can be seen as both a driver and an emergent property of hydrological and geomorphic processes. WG4 addresses the use of digital elevation models to assess hydrological and sediment connectivity quantitatively through indices at different spatial scales, from a single plot, to a whole catchment, to the regional scale. WG4 will summarise and evaluate (in cooperation with WG2) existing indices used (or useful) for the quantification of runoff and sediment connectivity, and foster the use and further development of such indices in future research proposals and land development plans. With the collaboration of WG1 and WG3, WG4 will discuss concepts and set forth requirements for the development of new indices that go beyond static, purely DEM-based approaches (i.e., structural connectivity) by accounting for dynamic, process-based aspects of connectivity and the local context, for example soil properties. The latter will be regarded both as an element of structural connectivity (through the spatial distribution of such properties) and as a driver of functional connectivity (by influencing processes that establish connection or disconnection). While DEM-based approaches also relate to processes (as topography forms the basis for process activity and pathways), WG4 envisages the computation of time-dependent connectivity indices, for example by incorporating the development of continuously saturated flow paths between sediment sources and the channel network during an event (see e.g. Reid et al., 2007). Four WPs have been designed based on this working strategy (Table 1).

WG5: Transition of connectivity research towards sustainable land and water management

Until now, connectivity research has mainly been carried out by natural scientists and important linkages and feedbacks with drivers of water and land management remained poorly studied. This WG will link connectivity research and socio-hydrology/geomorphology through coupling connectivity issues to stakeholder decision-making processes, adapting model-based scenarios of

connectivity to management applications for water availability (e.g. networks of reservoirs), soil conservation, natural hazard and environmental pollution (e.g. sudden flows of contaminants). It will produce (i) a framework for predictive modelling applications and land-management decision-support; and (ii) a set of guidelines for land- and water-management practitioners on how to deal with connected pathways and water- and land-surface processes on sudden (dis)connection of landscapes for hazard prevention. In so doing, it will ensure effective dissemination and demonstration projects for land and water management. WG5 will build on the outcomes of the other four packages: translating aspects of connectivity theory (WG1) to the socio-hydrological community through developing a common language, comparing and adapting connectivity monitoring guidelines (WG2) and existing
state-of-the-art guidelines, transferring the output of scenario-based models and indices of connectivity (WG3 and WG4) to decision-making protocols. The recipients of this knowledge are not only other scientists but also other sectors of society, especially those involved in planning and in the use of land and water; which will be ensured by actively engaging these communities in workshops during all phases of the Action. Six WPs have been developed for this WG to meet the set objectives (Table 1)

D.2 Scientific work plan methods and means

Tasks	Activity type					Objectives
	Workshop	Conference	Exchange/train	Web-based activity*	Think tank	
WG1						**Theory**
WP1.1	x	x				Compare connectivity definitions and concepts across different disciplines
WP1.2	x					Review studies of water and sediment connectivity
WP1.3			x	x	x	Use WP1.1 & WP1.2 to develop a theoretical underpinning for water and sediment connectivity
WP1.4	x					Evaluate output of WP1.3: temporal scales and variations of connectivity in various climatic settings
WP1.5	x				x	Develop a probabilistic approach to quantify connectivity from plot-, hillslope to catchment scale
WG2						**Measuring approaches**
WP2.1	x	x	x			Generate a list of methodologies to study hydrological

						and sediment transport connectivity.
WP2.2	x			x	x	Post-processing & uncertainty, methods to transform raw data into products and evaluate their quality.
WP2.3	x			x	x	Data mining, data pool of existing data sets, post-processed and evaluated following WP2.1/WP2.2.
WP2.4	x	x	x	x		Managing and interacting, to structure and manage the activities organised by this WG.
WG3						**Modelling approaches**
WP3.1				x		Web-based model benchmarking: model epistemology and structure
WP3.2	x			x	x	Comparing connectivity integration and functionality in existing models
WP3.3				x		Web-based data benchmarking: data structure and compatibility
WP3.4				x		Data comparability and integration of new datasets
WP3.5		x		x	x	Inter-comparison and evaluation of model results
WG4						**DEM-based, field-calibrated connectivity indices**
WG4.1	x		x	x		Foundations of DEM-based indices, linked to theory and field experience/data
WG4.2	x				x	Comparative assessment of existing approaches, setting up next generation indices
WG4.3			x	x		Connectivity, field data and sediment management
WG4.4	x	x				Research needs: developing more effective indices
WG5						**Transition of connectivity research towards sustainable land and water management**
WP5.1	x				x	Linking connectivity research and socio-hydrology
WP5.2	x	x	x		x	Design of a stakeholder decision making process for water and sediment connectivity issues
WP5.3	x		x		x	Defining common language between resource managers and natural scientists on connectivity
WP5.4			x	x		Modelling and management of water availability and sedimentation in a network of reservoirs
WP5.5	x	x			x	Sudden change – natural hazard, sudden flow of contaminants and how to communicate this to managers or the public
WP5.6			x	x		The sustainable use of an agricultural land to achieve productivity and soil & water conservation

E. ORGANISATION

E.1 Coordination and organisation

Considering the close inter-linkage of hydrological and sedimentary connectivity, the COST network will principally consist of hydrologists, geomorphologists, Ecologists and soil scientists. The Action will start with a plenary meeting to encourage as much cross-fertilization of ideas as possible, and to establish membership of the five Working Groups (WGs) that map onto the five objectives of the Action (Fig. 1). WGs will meet independently to address the focus of their tasks and to identify actions that members will carry out in their own countries. The results will be discussed at the next WG meeting. It is possible that new topics might emerge, that would require a new WG, if so, this will be supported. The Action will conclude with a final plenary meeting involving all participants. In addition to the WGs, the Action also will have a webmaster to coordinate the e-dissemination and e-learning tools. All partners will be required to make the findings of their activity and e-learning modules for students available on the website. In addition web-fora are intended to create a faster and more efficient communication in between the workshops and conferences where we can meet in person. Furthermore, these fora will enable people to update themselves on the progress of all Working Groups.

The Management Committee (MC) will consist of up to two representatives from each participating COST country, currently with >40% Early-Stage Researchers. A Steering Group (SG) within the MC will be formed, consisting of the MC Chair, Vice-Chair and the WG leaders . The MC, SG, and WG meetings will be will be held before or after an Action activity (e.g. workshop) whenever possible, to use the budget most effectively. MC and WG meetings will also be attached to, where possible to planned conferences (EGU –European Geosciences Union- general assemblies, EGU Soil System Sciences Series, IAG-International Association of Geomorphologists-or IAHS - International Association of Hydrological Sciences- sub-group meetings and other conferences to be identified later). In order to facilitate greater dialogue and progress in meeting objectives, additional web-based meetings using web conference facilities / software will be implemented. To ensure the coherence of the different WGs, the Actionwill convene a session at the annual EGU meetings during the lifetime of the Action, at which participants can present their activities. The resulting wider publicity for the Action will encourage colleagues to join the Action. WGs, plenary and EGU meetings will be used to especially encourage our young students to travel to the different partners and benefit from their expertise and additional view points on the concept of connectivity. The WGs are formed to give structure to the Action, however, the Action aims to have as much interaction between these WGs as possible. The scientific programme will include plenary meetings once a year and grouped workshops of different WGs at appropriate stages along the progress of the Action. In addition, workshops at field sites will be organised where people from different disciplines and WGs will be invited to share their view on the specific research questions on the visited site. This approach will provoke more discussion and has the potential to bring the research field to a higher level of integration.

This Action will start with an interdisciplinary and international community of research and practice, initially with participants from 23 COST countries and participants from several International Partner countries. The initial participants involved in the development of this Action, come from a wide range of European countries. In addition, the participants will involve end users including land-use planners/ landscape designers and policy-makers at EU, national and regional levels. This Action will provide a flexible framework open to any country and participants. It permits the inclusion, at the implementation stage, of ideas and activities not foreseen during the preparation of the Action. The Action will encourage participation from unrepresented sectors and disciplines and Early-Stage Researchers in particular; which was started in the proposal phase by having a high number of ESRs among the group of researchers that contributed to this Action and that are identified to lead the MC and WGs.

E.2 Working Groups

Five Working Groups will be formed (Table 2), each focussing on a different aspect of connectivity research (see details section D). The results of some Working Groups will be used as input in others. The Action aims to organise specific meetings to facilitate the interaction between WGs. Special attention will be given to WG5, to which all other WGs need to contribute. To enable this, the Action plans to have in the 2^{nd} and 4^{th} year a plenary meeting focussing on societal issues raised by management institutes and other relevant stakeholders.

Table 2: Illustration of the management structure.

<table>
<tr><td colspan="3">Management Committee (MC)= MC Chair + Up to 2 representatives from each participating COST country
Steering group = MC Chair and WG leaders
Webmaster for e-learning/e-dissemination</td></tr>
<tr><td colspan="3">WG 1: theory
Leader + WP Committee
Short term members</td></tr>
<tr><td>WG 2: Measuring Approaches
Leader + WP Committee</td><td>WG 4: Indices and scaling
Leader+ WP Committee</td><td>WG 3: Modelling Approaches
Leader + WP Committee</td></tr>
</table>

Short term members	*Short term members*	*Short term members*
WG 5: Transition of connectivity research towards sustainable land and water management **Leader +** *WP Committee* *Short term members*		

E.3 Liaison and interaction with other research programmes

There are a number of institutes that have synergy with this Action. Researchers committed to this Action are currently running a large number of projects related to this Action. They have agreed to share their insights with other researchers and coordinate and organise activities to enable cross-fertilization between the different project and partners.

E.4 Gender balance and involvement of Early-Stage Researchers

This COST Action will respect an appropriate gender balance in all its activities and the Management Committee will place this as a standard item on all its MC agendas. The Action will also be committed to considerably involvement of Early-Stage Researchers. This item will also be placed as a standard item on all MC agendas.

The Steering Group (SG) will consist of a high number of ESRs (out of the 12 people identified as initial members of the SG, 6 are ESR). Furthermore, a high number of female scientists will be involved in the MC (~ 40 %, including the Chair of the Action). Also, the Action has ensured a balance between scientists from southern and northern Europe. Each Working Group (WG) consists of Leader, and WG Committee consisting of 4-8 MC members. Typically at least two Early-Stage Researchers will sit on each WG Committee.

F. TIMETABLE

Tasks	Deliverables	Year			
		1	2	3	4
WG1	Theory				
WP1.1	Think tank to write paper on connectivity definition comparison	X			
WP1.2	Workshops and web forum on research approaches in Europe.	X			
WP1.3	Selected definitions and data to study different approaches		X		
WP1.4	Identify conceptual models for various climatic settings & scales		X		

WP1.5	Probabilitistic, quantative unscaling approach for connectivity			X	
WG2	**Measuring approaches**				
WP2.1	Standardize: survey protocols for various spatial/temporal resolutions	X			
WP2.2	Manuals: data post-processing and uncertainty analysis.	X	X		
WP2.3	Hierarchized data pool open access online for participants			X	X
WP2.4	Identified conceptual models for different climatic settings and scales			X	X
WG3	**Modelling approaches**				
WP3.1a	Online resources: model benchmarking and evaluation of connectivity	X			
WP3.1b	Scientific publication: approaches to model connectivity	X			
WP3.2	Teleconferences: data quality control and provision of metadata	X			
WP3.3	Scientific publication: different aspects of model inter-comparison		X		
WG4	**Indices and scaling**				
WP4.1	Evaluation connectivity indices: Review paper and web-database	X			
WP4.2	Report on comparability and predictive ability of indices		X		
WP4.3	Collection of requirements for new indices			X	
WP4.4	Paper(s) on new indices and research needs for more effective indices				X
WG5	**Transition of connectivity research towards sustainable land & water management**				
WP5.1	Established contacts and links between the two communities	X	X		
WP5.2	Workshops: identify best models for an effective management tool	X	X	X	
WP5.3	Think-tank: define common language to foster good communication		X	X	
WP5.4	Workshop: Linking connectivity and societal issues		X	X	X
WP5.5/5.6	Integrating knowledge of the rest of WGs during Training Schools			X	X

G. ECONOMIC DIMENSION

The following COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: AT, BE, CH, CZ, DE, EL, ES, FR, HU, IE, IL, IT, LT, LU, NL, NO, PL, PT, RO, SE, SI, SK, UK. On the basis of national estimates, the economic dimension of the activities to be carried out under the Action has been estimated at 92 Million € for the total duration of the Action. This estimate is valid under the assumption that all the countries mentioned above but no other countries will participate in the Action. Any departure from this will change the total cost accordingly.

H. DISSEMINATION PLAN

H.1 Who?

The target audiences and the methodology of dissemination of the results of the Action are strongly related (Table 4). An Action-specific website will be set up, with links to the COST website for general information. Recognizing the time and energy required to set up and maintain an effective web site, the Action will appoint an Early-Stage Researcher, associated with the Action coordinator, as web-manager. The web site will perform three functions. First it will enable dissemination/exploitation of the Action results and data, including via the use of social media as well as by more traditional reports. Secondly, there will be a forum for Members only, to share ideas and ask questions. Thirdly, there will be an area to post e-learning modules that will be the result of STSM and on-site trainings for young scientists. Fourthly, the website will be used as a platform for web-conferencing of all small workshops and conferences organised by the Action to provide maximum connection of researchers and minimize our carbon footprint.

H.2 What?

Table 4: Dissemination Plan: target groups and methodologies of dissemination	
COST Action participants and scientists outside of the Action interested in the topic of connectivity in Earth Sciences	Web-based discussion platforms; web-conferences, (see H3 for more info on website design) for research and educational purposes; Short Term Scientific Missions for PhD and Senior scientists and workshops and conferences (see H3 for topics and sites); final conference with invited key-scientists and decision makers; Think-tanks on specific research questions; outcomes posting on website; scientific publications and presentations in conferences; exchange of students (mostly PhD) among the Actions partners; Summer schools (8-10 days) on research sites of partners (see H3); Scientific publications, including special issue publications in open access peer review journals
Land&water managers *	Website with e-learning modules; General publications in public media; Workshops designed for this target group
Policy makers **	Final conference; Reposts targeted towards this end-users group; e-learning modules on website
Local stake-holders/public	Brochures and flyers in different languages; Online database with readily retrievable data accessible to all stakeholders;

*planners, consultants in fields dealing with land and water management including ecologists, engineers, environmental managers,
environmental officers, service providers) **European and other national and international bodies such as national environment agencies; the European Commission on Environment; UN conventions related to land and water management, FAO etc.

H.3 How?

Field sites for Short Term Scientific Missions (STMS)

In many of the participating countries partners have sites where potential connectivity research could be carried at catchment scale (SI, Drajonja and Bovec basin; LI: Dzukija National Park; LUX: Attert River basin; IT: Val Venosta valley and Grigno catchment; ES: Alqueria, Lorca basin, Murcia, SE Spain; Carcavo Basin (Murcia, Spain) and River Cinca (NE Spain); AT the Danube floodplains, Horlachtal and Kaunertal (Central Alps), Thayatal (Bohemian Massif), Kleinsölktal (Central Alps); IL: Bikhra and Eshtemoa watersheds in the Negev; USA : Sevilleta LTER site, New Mexico; PL:Stara Rzeka research catchment and its sub-catchments (Dworski and Brzeźnicki); HU: Zala river; catchment of Lake Balaton, DE: Lahnenwiesgraben and Reintal catchments, Northern Calcareous Alps. There are also partners that have existing outdoor laboratories in place to facilitate the setting up of joint research, and to use these sites illustrate their research during workshops or Short Courses (SE; National Geosphere Laboratory in the Oskarshamn region, including the Äspö Hard Rock Laboratory; ES: Experimental field site, Aranjuez, South of Madrid; GR: Navarino Environmental Observatory, Messinia; UK: Dartmoor national park, Exmoor National Park (two sites), three sites in the SW UK; PL: Field Research Station in Łazy). The last category of sites among our partners are experimental watersheds (ES: Network of Agricultural Experimental Watersheds in Navarre; AT: Hydrological Open Air Laboratory (HOAL); FR: Roujan and Peyne basin; PT: Urban watersheds (Ribeira dos Covões and the Ribeira da Arregaça); agricultural catchment (Macieira de Alcôba) and mountain catchments (Valtorto catchment). Or experimental station such as the El Teularet – Sierra de Enguera in Eastern Spain. The variety of sites to our disposal will generate the potential for researchers to learn from each others' experiences and exchange ideas and promote new research ideas.

Workshops/small conferences (also web-conferences)

Many of the researchers that expressed their interest for this Action have indicated to be willing and able to organise a workshop in either a very specialized topic that would fall into one of the WGs; but also using a field site to provoke and initiate the integration of the different disciplines that will be brought together to bring convergence in the research done in the field of water and sediment connectivity. An example of a specialized workshop will be on new measurement and modelling approaches for investigating surface and sub-surface connectivity in the hillslope-riparian-stream continuum. An example of a conference on applied science could be on stakeholder engagement by participatory workshops. Currently one of the weaknesses of water and sediment connectivity research is the implementation of scientific measures, although it should be considered as the ultimate objective of this area of knowledge. The origin of this gap may be the weak link between scientists and stakeholders. Workshops in different countries to facilitate the contact between them should have a similar structure but they should address the particular local problems and possible solutions at each site, considering both the opinions of researchers and stakeholders. The benefit of this type of workshop include: a general vision of different points of view for different sites in Europe regarding the application of environmental measures; a valuable experience for young researchers responsible for the future research in this area of knowledge; a tool to compare successes and failures in the implementation of runoff and erosion measurements in different countries; a compilation of knowledge from different actors involved in land management. This could be published in different media towards the end of the Action.