ADB

Technical Assistance Consultant's Report

Project Number: 47061-001
October 2015

People's Republic of China: Institutionalization of Urban-Rural Environmental Master Planning to Guide Environmentally Sustainable Urbanization in the People's Republic of China

(Financed by the Technical Assistance Special Fund and Urban Environmental Infrastructure Fund)

Report 2: Technical Guidelines

(Pages 1–70)

Prepared by the consultants of TA 8537-PRC: Institutionalization of Urban-Rural Environmental Master Planning to Guide Environmentally Sustainable Urbanization in the People's Republic of China

For the Ministry of Environmental Protection

Asian Development Bank
TA8537 (47061) PRC

Technical Assistance Consultant Report:

Institutionalization of Urban-Rural Environmental Master Planning to Guide Environmentally Sustainable Urbanization in the People's Republic of China

Protecting the PRC's Green Land from Urban Development, Urban Sprawl and Overdevelopment

Report 2
TECHNICAL GUIDELINES

Asian Development Bank
TA8537 (47061) PRC

Institutionalization of Urban-Rural Environmental Master Planning (UREMP) to Guide Environmentally Sustainable Urbanization in the People's Republic of China

A note on the outputs of this project

The Asian Development Bank Technical Assistance Project TA8537 (47061) PRC, Institutionalization of Urban-Rural Environmental Master Planning (UREMP) to Promote Environmentally Sustainable Urbanization in the People's Republic of China, delivered the following **four reports**.

Executive Report: Summary of UREMP in the PRC - Protecting China's Green Land from Urban Development, Urban Sprawl and Overdevelopment provides a comprehensive summary of UREMP and of the issues to be addressed in protecting China's Green Land in the context of continued rapid urbanization. The report provides a description of the methods and techniques to be used, recommendations for policies and for institutionalising urban-rural environmental master planning at various levels of government in the PRC, and lessons from successful examples of environmental protection in China and elsewhere.

Report Two: Technical Guidelines of UREMP (this report) provides technical details in the form of a manual and step-by-step guide for how to practically plan and implement UREMP, including approach, methods and techniques for mapping, analysing, assessing, zoning and evaluating Green Land within and surrounding urban areas where environmental assets may be at risk from development.

Report Three: Recommendations for Policies and Institutional Arrangements of UREMP provides details on procedures for setting up a legal framework and administrative regulations, and an institutional framework to enable UREMP to become an effective and operational instrument.

Report Four: Domestic Pilots and International Best Practice Cases of UREMP offers lessons from best practices in the PRC and elsewhere as a basis for possible solutions for protecting the PRC's Green Land, using theory, policies, institutional arrangements, methods and techniques from best practice cases.

Acknowledgments

This Technical Assistance Project is developed in cooperation between the
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Ministry of Environmental Protection, the People's Republic of China

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1 Executive Summary

The Ministry of Environmental Protection (MEP) suggests that all over the PRC the scarce resource of land should be treated with great care and land-use efficiency when developed, and ensure that natural and green environment is protected from wasteful usage of land. Development and construction need to be balanced, careful and responsibly making sure that the environment and ecosystems will be protected for many generations to come, and therefore the next phase of PRC's urbanization needs to be more environmentally sustainable. Ecosystems and important landscapes, and farmland are precious and must not be disturbed.

MEP has determined that environmental protection will be strengthened and given greater priority through the process of Urban-Rural Environmental Master Planning (UREMP). The development of UREMP Plans recognizes that in reality protecting green space from urban development and overdevelopment is an extremely difficult challenge, against competing interests for land. Environmental protection requires explicit development and human activity controls in the form of environmental zoning, with maps, standards, land use criteria and procedures, to be incorporated in urban and regional strategies, master plans and detailed development plans. The UREMP Plan will provide such an environmental zoning instrument.

The structure of the Technical Guideline is accordingly based on defining the UREMP Area considering landscape integrity, bioregions and territories at risk from urban development and overdevelopment, i.e. all 18 or 20 city clusters as planned in the New Type Urbanization Plan for the PRC (2014-2020) and all cities and their rural hinterlands. The objectives are building the UREMP partnership, adopting data standards, and analysing land and water areas, and considering the five factors: ecosystems services, Green Land, water, air and the potential for restoration.

The specific objectives and methods of preparing a UREMP Plan are described in eight Steps in this report, which provide step-by-step technical guides to implementing UREMP. Within these eight Steps there are 34 technical Modules describing methods of analysis and synthesis on specific aspects of environmental protection and planning, and in this volume principles are provided and illustrated intended as guides and toolkits. Individual Modules may be relevant to more than one of the steps. They are listed in Table 2-0-1 and described in Sections 3 to 10 below.

It is important to acknowledge that in order to identify the UREMP boundaries and the essential environmental protection areas only a few key Steps already deliver the most critical result getting the redlines right at a very high degree. These include the key Steps 3, 4, 5, and 8, while Step 6 is also important especially in the PRC's mega-agglomerations. The methods and modules needed can be widely understood and carried out quite simply and do not require complex analysis and computation. Steps 7 are optional and should be considered in a fully sustainable environmental management and in a comprehensive way to provide and harness ecosystems services.

One of the results of UREMP is environmental zoning with a delineation of red, yellow and green lines based on comprehensive, rigorous analysis of a planning area. The first requirement is therefore to define the UREMP Area, and to promote partnerships among the neighbouring jurisdictions.

The second requirement is to adopt an appropriate platform for the collection, integration, mapping and sharing of the data on which the analysis of the UREMP Area will be carried out.

To promote clear guidance, the concluding maps of a UREMP Plan will consist of three zones. In the red line zone environmental values are highest and human activities of development, construction, rebuilding and expansion of production are forbidden and inappropriate land uses and buildings are removed. In the yellow line zone all forms of land use and development are strictly controlled to ensure, as far as possible, that natural ecosystems are not disturbed and green space, such as grassland, forest land, rivers, lakes and wetlands, cannot be reduced. The third zone is the green line zone. This applies to all the remaining land, subjecting it to the injunctions stated at the beginning of this section – briefly, that land use should be economical and intensive, and that development should be environmentally responsible and sustainable.

The third requirement is to analyse all aspects of the environmental value of land and water area within the UREMP Area, and to assess the relative values of those areas in terms of different parameters. In this Technical Guideline, there are five factors: ecosystems, land, water, air and remediation.

The result of this comprehensive analysis is five sets of maps showing indicative protection zones resulting from the assessment and evaluation of the five main parameters. It is by overlaying these indicative zoning maps, and by integrating their ranking of the different areas, that the areas of highest environmental value can be identified. This can only be effective if the sectoral analyses are objective, quantified and rigorous. The results must be credible, and must be persuasive in negotiations within and between jurisdictions. As noted above, it is the purpose of this Technical Guideline to enable the preparation of environmental protection zones to be objective, quantified and rigorous.

2 A systematic process for Urban-Rural Environmental Master Planning

Forests, wetlands, river meadows, farmland, green spaces in general, and green networks provide essential ecosystem services: habitat for wildlife and conservation of biodiversity, production of oxygen, protection of drinking water, absorption of noise and pollutants in air and in water, lowering summer temperatures in urban areas, reduction of stormwater and flooding, and many more ecosystems services. Natural and green spaces provide many economic services i.e. in the form of farmland, and enhance public health and wellbeing, strengthen communities, and provide recreational opportunities, and increase land values nearby.

These essential green areas in cities and their rural hinterlands are not appropriately valued and not adequately protected from urban development, urban sprawl and overdevelopment. Much of this valuable open land has already been lost to development. Even in light of the amended law of environmental protection in the People's Republic of China (PRC, 2014) effective protection of green land (both natural and cultivated) especially in cities and within growing agglomeration regions remains a serious challenge. The remaining green areas continue to be at risk from urban development and sprawl.

To protect important green space in and surrounding cities, two major measures are required.

- **Land analysis and mapping.** Land in and urban and its surrounding rural areas must be analysed, assessed, mapped, zoned and ranked. Specific areas will be highly ranked for the ecosystems services it provides for example for water source protection, flood risk management (flood plains), habitat integrity and biodiversity, landscape integrity, agriculture, recreation, air filtration and microclimate improvements and others. This analysis and evaluation must be sufficiently objective, quantifiable and rigorous to enable the highly ranked areas to be accurately delineated and provide legal status for their appropriate protection. The approach, methods and techniques for this work are detailed in this Technical Guideline (Volume 1) of UREMP.

- **Environmental protection through environmental zoning that forbids/limits/regulates development in the respective zones**. Urban-rural environmental protection needs a sound legal basis, clear administrative regulations and a societal consensus of the need to protect essential (and even desirable) green space. For the PRC needed are amendments to the current national environmental protection law and the current administrative regulations to require urban and rural administrations to prepare a common UREMP and include the environmental protection zones in all urban and rural master plans. Urban-rural environmental protection is based on national, regional and basin-wide environmental protection provisions issued by the State Council and instruments issued by ministries and commissions; on specific measures of the Ministry for Environmental Protection; on the planning instruments of the PRC's 18 city-clusters as defined in the New Type Urbanization plan for the PRC (2014-2020); the PRC's 655 cities (direct-controlled municipalities, sub-provincial cities, prefecture-level cities and county-level cities) and national development zones; and on other local regulations. For urban-rural environmental protection to be effective, significant institutional change is needed towards interdepartmental cooperation and cross-jurisdictional coordination and joint planning building partnerships within and among jurisdictions within a UREMP planning area defined by a bioregion. The institutional partnerships will integrate UREMP as an urban-rural environmental protection and planning instrument, develop joint monitoring and enforcement regimes, promote public environmental awareness engaging stakeholders and communities. The necessary steps and procedures for setting up a legal framework and administrative regulations, and an institutional framework to enable UREMP to become an effective and operational instrument are detailed in the Policy Recommendations and Institutional Framework (Volume 2) of this UREMP report.

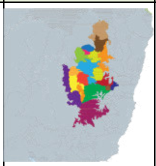
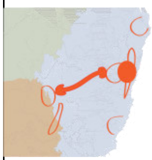
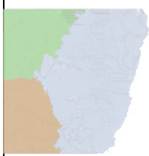
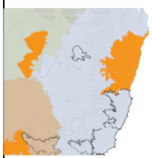
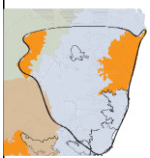
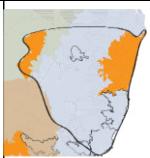
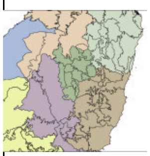
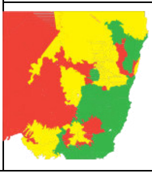
This Technical Guideline describes the eight *Steps* that are normally required for the preparation of a new UREMP Plan. They are listed in Table 2-0-1 and described in this Section of the report.

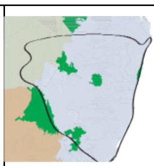
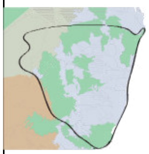
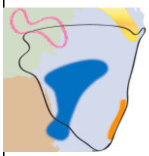
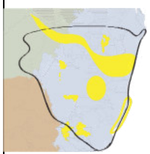
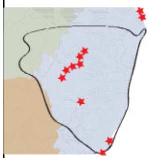
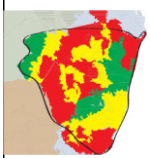
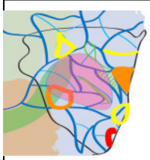
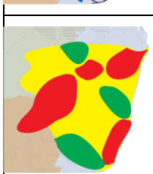
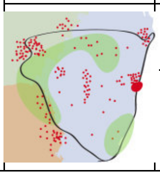
Within each Step are a number of Modules, each providing technical guidance for a specific issue or task. The Modules describe methods of analysis and synthesis on specific aspects of environmental protection and planning. Principles are provided and illustrated. This volume is intended as a set of guides and toolkits.

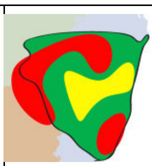
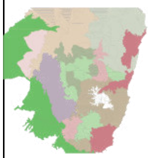
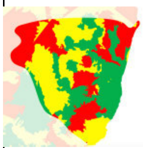
There are 34 *Modules*. Individual Modules may be relevant to more than one of the steps. They are listed in Table 2-0-1 and described in the following Sections of this report.

Table 2-0-1 Steps and Modules for UREMP zoning

The diagrammatic maps are hypothetical examples, (i) to illustrate the kind of mapping that might be required for each Module, and (ii) to show the Steps at which red lines are mapped and then integrated.

8 Steps	A map for each Module	34 Modules
Step 1: Establish the UREMP Area and Partnership		**Module 1A: Map the boundaries of bioregions and subregions** This is one of two essential first tasks: to describe and document the basic characteristics of the natural environment in the regions where a UREMP Area may be defined. Note: bioregions and subregions are higher-order divisions and may overlap the diverse ecosystems and landscapes mapped in Step 3.
		**Module 1B: Map urbanized areas and areas exposed to risk from urban and suburban development and sprawl due to proximity and/or planning** This is the second of the two essential first tasks: to *describe* and document urban and development pressure in the regions where a UREMP Area is to be defined.
		**Module 1C: Document and adopt objectives, controls and evaluation standards and methods** National and province-level legislation, controls, standards and methods enable UREMP planners to make environmental protection planning more effective at every level.
		**Module 1D: Agree on the jurisdictions that might be included in the UREMP partnership** This task involves consultation and negotiation with jurisdictions that may be partners in making the UREMP Plan, or may be partners on specific problems.
		**Module 1E: Agree on the boundary of the UREMP Area** This crucial preliminary task involves consultation and negotiation to determine the UREMP Area and the roles of any partner jurisdictions.
Step 2: Prepare agreed standards for the UREMP Atlas		**Module 2A: Adopt data standards and platforms**
		Module 2B: Adopt GIS standards and platforms
		Module 2C: Adopt mapping standards, base maps, methods and models
Step 3: Prepare an Ecosystem Zoning and Protection Map		**Module 3A: Map and assess ecosystems and landscapes** Document and map the *state* of the environment (values and sensitivity/vulnerability), and document and map *pressures* on the environment.
		**Module 3B: Indicative ecosystems protection zoning and mapping** The first red line map, integrating the complex and competing values of the ecosystems services assessed in Module 3A.

Step 4: Prepare an Indicative Zoning Map for Green Land Protection		**Module 4A: Identify and map forest priority areas**
		**Module 4B: Identify and map agricultural priority areas**
		**Module 4C: Identify and map mineral resource priority areas**
		**Module 4D: Identify and map soil conservation areas**
		**Module 4E: Identify and map priority hazardous areas**
		**Module 4F: Indicative Green Land protection zoning and mapping** The second red line map, integrating the complex and competing values of the Green Land areas assessed in Modules 4A, 4B, 4C, 4D and 4E.
Step 5: Prepare an Indicative Zoning Map for Water Quality Protection		**Module 5A: Determine the scope of the water environment and spatial control units**
		Module 5B: Develop surface water quality models
		**Module 5C: Assess priorities for protecting rivers, lakes, wetlands and reservoirs**
		Module 5D: Assess priorities for flood risk management
		Module 5E: Assess priorities for water source protection
		Module 5F: Assess priorities for the protection of riparian and coastal areas
		**Module 5G: Indicative water quality protection zoning and mapping** The third red line map, integrating the complex and competing values of the Water environment assessed in Modules 5A, 5B, 5C, 5D, 5E and 5F.
Step 6: Prepare an Indicative Zoning Map for Air Quality Protection		**Module 6A: Assess priorities for microclimate protection areas**
		Module 6B: Develop a regional atmospheric flow model
		**Module 6C: Develop a regional pollution source model**
		Module 6D: Develop a regional atmospheric absorptive model

		**Module 6E: Indicative air quality protection zoning and mapping** The fourth red line map, integrating the complex and competing values of the Air environment assessed in Modules 6A, 6B, 6C and 6D.
Step 7: Prepare an Indicative Zoning Map for Ecosystems Restoration		**Module 7A: Identify and map the potential for habitat and biodiversity regeneration** **Module 7B: Identify and map the potential for water body and river restoration** **Module 7C: Identify and map the potential for urban greening and open space** **Module 7D: Identify and map the potential for brownfield remediation** **Module 7E: Indicative environmental restoration zoning and mapping** The fifth red line map, integrating the complex and competing values of the areas assessed in Modules 7A, 7B, 7C, 7D and 7E.
Step 8: Integrated Environmental Protection Zoning		**Module 8A: Environmental protection zoning** The UREMP red line map, integrating the environmental protection zones and controls in the red line maps produced in Modules 3B, 4F, 5G, 6E and 7E.

The steps are generally carried out in the order presented. However it is important to note that the UREMP process is not entirely linear. Hence it is important to reflect and adapt former steps when next steps were completed to ensure findings from one step will inform other steps. When decisions are made, however, the sequence in generally in the order of the steps as presented.

2.1 Step 1: Establish the UREMP Area and Partnership

Six of the pilot cities have shown the way towards urban-rural environmental protection zoning by creating red line and yellow line zones within the boundaries of their city. These pilot projects have successfully tested and generated techniques and procedures, but they are not a final model for the institutionalisation of UREMP. For environmental protection to be effective, a UREMP area will need to be much larger than a single urban jurisdiction. There are five main reasons for this.

- It is intended that for all 18 city clusters planned in the New Type Urbanization Plan for the PRC (2014-2020) UREMPs will be produced as priority, and further cities and their rural hinterlands will be required to prepare UREMP Plans.

- More importantly, urbanisation is taking place in large and small cities and in other jurisdictions across the PRC, typically in the form of city clusters, comprehensive urban regions, within which cities are competing for investment and resources. In one extensive urban system, housing, transit, infrastructure, physical and human services, etc, need to be planned across jurisdictions. The largest of these urban systems are the twenty city clusters. In the initial stages of UREMP, these city clusters are most likely where the highest priorities are for environmental protection, and where institutionalisation of UREMP is most likely to be successful.

- Municipal and other boundaries divide farmland and other green areas, and fragment river basins, forest areas, wetlands and other environmentally significant systems, making protection more difficult and less likely. Individual cities are likely to avoid responsibility for protecting such an area, since they can only manage a part of the area.

- To be efficient and effective, environmental protection plans must be based on environmental regions – bioregions, watersheds, catchments, climate zones, etc – that should be managed in an integrated way. In the landscape, geophysical patterns – that determine plant and animal communities and processes at the ecosystem scale – are unrelated to administrative boundaries, but must be the basis for effective measures for environmental protection.

- Understanding and then recovering biodiversity can only be effective at the scale of bioregions and subregions. Bioregions are defined using data about climate, geology, landform, drainage, vegetation, wildlife and land use. Subregions, which are based on finer differences in biophysical attributes including geology and vegetation, can provide more detailed information about the landscape and are used for planning and conservation.

Therefore, the environmental protection plans will normally relate to a number of jurisdictions. The first critical step is to reach agreement, based on the scientific evidence, on the boundaries of the relevant environmental regions and, at the same time, on the composition of the UREMP partnership made up of jurisdictions within a city cluster or urban region.

The formation of the UREMP partnership will require collaboration and cooperation between jurisdictions, and between agencies within jurisdictions. In short, the Peoples Governments and agencies within the proposed environmental region(s) must form active partnerships to deliver effective environmental protection.

It will be necessary for governments and agencies to invest significant resources in building cooperation and coordination, and they will need to set up specific mechanisms such as steering committees and working groups to deliver these outcomes.

There must also be community awareness across the region, and interactions between the stakeholders of the partner jurisdictions.

Agreement on a boundary for the preparation and adoption of environmental protection zones follows naturally from agreement on bioregion boundaries and agreement on the composition of the UREMP partnership. However, compromises will need to be negotiated, balancing the effectiveness of environmental protection against the feasibility of the coordinated implementation of local and municipal development control. In the end, boundaries for the proposed environmental protection plan must be agreed and adhered to.

The resulting UREMP protection zones will cover the whole UREMP Area. These environmental protection zones will need to be translated from the environmental protection plans into the urban and regional master plans and development plans of the individual jurisdictions.

Step 1 (Establish UREMP Area and Partnership), Step 2 (Prepare agreed standards for the UREMP Atlas) and Step 3 (Prepare an Ecosystem Zoning and Protection Map) are mutually dependent and must be carried out iteratively and in parallel. The finalisation of Steps 1, 2 and 3 enables all subsequent Steps to be finalised. The other Steps – Steps 4, 5, 6 and 7 –focus on different aspects of environmental services and values, namely non-urban Green Land, water, air and remediation. Each of these Steps generates several analytical maps and a consolidated map, called an *indicative zoning map* that delineates the land that has the highest need for environmental protection in terms of values derived from ecosystems, land, water, air and remediation. It is from these five indicative zoning maps that it is possible, based on holistic analysis and assessment, to define the areas that should be within the red line environmental protection zone and the yellow line environmental protection zone.

2.2 Step 2: Prepare agreed standards for the UREMP Atlas

Step 2 is concerned with process and format rather than content: shared standards for collecting and managing data, agreed ways to manage geographical information systems (GIS), and a common format for maps. These standards are essential if the data collected by many agencies is to be accessible, comparable, integrated and kept up to date. It is also essential if all the data and spatial information for the UREMP area is to be integrated in the UREMP Atlas.

The UREMP Atlas is not a document or a publication. It is an emerging network of internet databases, owned and maintained by the agencies which collect and update the data and maps, with rights of contribution, editing, analysis and access assigned to various entities according to the protocols and procedures agreed by the UREMP partnership.

2.3 Step 3: Prepare an Ecosystem Zoning and Protection Map

The effectiveness of environmental protection depends on (i) the quality of measurement and mapping of land and ecosystems, and (ii) whether the value of ecosystems services to society and economy and the environment can be demonstrated convincingly.

It is essential that ecosystem services are placed strongly at the centre of the early stages of preparing a UREMP Plan. After developing an understanding of the essential environment characteristics of the potential UREMP Area and agreeing to the composition of any UREMP Partnership (Step 1), and after establishing a mapping and data platform (Step 2), the UREMP planners must broadly identify the ecosystems that provision and regulate the environmental benefits received by human society, and provide cultural benefits.

In the long run, it is essential that the UREMP planners document the characteristics of the UREMP Area (possibly including topography, soils, geology, hydrology, mesoclimate, habitat and biodiversity, flora and fauna, areas of land use, areas of land cover types, water quality, air quality, natural productivity for food and fibre, emission, fixation and storage of greenhouse gases, and cultural assets) in the process drawing on, and revising, the findings in Step 1.

The UREMP planners will document and map the *driving forces* affecting the environment (interests, motivations, market forces, regulations, traditional practices, etc).

The UREMP planners will document and map the *pressures* on the environment (development and other pressures, such as urban expansion, infrastructure, vegetation clearing, mining, traffic, sealing of the surface, and pollution load, as initially identified in Step 1).

The UREMP planners will document and map the *state* of the environment – values, sensitivity, vulnerability – for critical ecosystem services, such as climate protection (sequestration and storage of greenhouse gases), soil fertility and productivity for agriculture and forestry, water provisioning (surface catchments and ground water), storm water retention, local climatic functions, renewable energy potential, cultural ecosystem services (aesthetic value, heritage, recreation).

Where data is available, the UREMP planners will assess the *impact* of the identified pressures on the identified ecosystem services.

In all cases, the UREMP planners will broadly identify the *responses* that are necessary to reduce impacts and reverse the loss of ecosystem services.

As shown clearly in Section 5 (Modules in Step 3) below, the theory, techniques and practice of valuing ecosystem services is on the cutting edge of science and practice. While improvements in concepts and methods are being made all the time, including notably by the environmental scientists of the PRC, there is no settled model or methodology for comprehensively valuing ecosystem services and managing change to protect those ecosystem services.

UREMP is a major (and globally significant) initiative to protect the environment, and must take advantage of environmental protection strategies that are simple, tested, and feasible. Assessing the value, sensitivity, and vulnerability of ecosystems that provide services to society are an essential element of the UREMP process. Initially, these assessments may be constrained by unfamiliarity, and shortages of time, funding and data. Nevertheless, it is essential that this work begins, so that it can continue to improve and evolve with the institutionalisation of UREMP.

Ecosystem analysis results in a series of maps (supported with evidence, GIS data, and assessment procedures) that details the relative values of land across the UREMP area, for a number of different factors including aspects of biodiversity, diverse ecological communities, diverse ecosystem services, and considerations of carbon substitution and sequestration.

When these maps are overlaid, areas of highest ecosystem value can be defined based on evidence and clear criteria.

2.4 Step 4: Prepare an Indicative Zoning Map for Green Land Protection

Non-urban land (Green Land) in the UREMP area may be in a relatively natural state, in which case its value to the economy and society is measured in Step 3: Prepare an Ecosystem Zoning and Protection Map. It may also be used as a natural resource for agriculture, pasture land, aquaculture and mining, and still have high values for the protection of plant communities and wildlife, for maintaining visual amenity and recreational opportunities, for producing oxygen, for improving the urban-rural micro-climate, for filtration of water and groundwater recharge, for reducing atmospheric carbon dioxide, and for other environmental benefits. Step 4 measures the values of Green Land in the UREMP Area, so that there can be realistic estimates of the values that would be lost if the land is converted to urban uses (city expansion, industrial production, infrastructure, tourism, recreation, etc).

Estimates also need to be made of the losses of land through over use, erosion, salinization, desertification and pollution; and potential losses from natural hazards such are landslide, floods, bushfire and storms, and from rising sea levels.

Notwithstanding the value of green land to the environment, the economy and society, all land in the UREMP Area may also have a commercial value as a site for development. Land with high environmental values may, as a result, have very high value for urban development, because of its proximity to water and to natural areas, because of its clean air and views over the landscape, because of its access to resources and industrial inputs, etc. These values of land as a site for development need to be compared with the existing or potential value of land as a natural resource. Step 4 estimates those values and therefore allows a holistic assessment to be made of the real value of land in the UREMP Area.

As in Step 3, this assessment cannot be effective if it is based on the analysis only of land within the UREMP Area. Factors outside the UREMP Area, such as the size of populations nearby, or the shortage of agricultural land in the region, or alternatively the abundance of agricultural land beyond the boundaries of the UREMP Area, must be systematically taken into consideration.

The result is a series of maps (supported with evidence, GIS data, and assessment procedures) that document the relative values of non-urban land across the UREMP Area, whether used for farming, forestry, extractive industries or other purposes, and/or which show the potential for reversing the loss of productive land through over-use, and/or which show the constraints on land for both productive and urban uses. These maps allow potential protection areas to be identified, according to industry and potential benefit.

By overlaying and integrating this information, it is possible to prepare maps showing land with the highest value as a natural resource, and thus indicative areas for environmental protection. This Technical Guideline details the aims and methods for the preparation of indicative non-urban green land zoning.

2.5 Step 5: Prepare an Indicative Zoning Map for Water Quality Protection

Water as an environmental service – whether as aquifer, waterbody or watercourse, whether in a relatively natural or altered state – is crucial for the conservation of biodiversity, for the protection of plant communities and wildlife, for maintaining visual amenity, for reducing atmospheric carbon dioxide, as a sink for noxients and emissions, and for other benefits to the economy and society. These environmental services are measured in Step 3, Ecosystem analysis. Step 5, Water quality protection, measures the value of water as a resource, for urban water supplies, food production and processing, irrigation, industrial and other urban processes, waste removal, landscaping and other economic and social purposes.

Rainwater may be an undervalued resource which can be collected in urban areas and used in all the ways that existing water resources can be used, thus conserving those resources and facilitating their rehabilitation where desirable. In relevant places, the potential for collecting and using rainwater in urban areas needs to be considered, assessed and mapped.

Water and water environments are at risk from most forms of urban development, and from direct pollution, run-off pollution, air pollution, land clearing, earthworks, erosion, siltation, and, in the longer term, from climate change. Water also poses risks, through carrying pollution and disease, and through flooding and sea level rise. All of these aspects need to be considered in a holistic assessment of the value of water to the UREMP Area, and the relative values of protecting water-related areas compared to their use for urban development (city expansion, industrial production, infrastructure, tourism, recreation, etc).

The result is a series of maps (supported with evidence, GIS data, and assessment procedures) that document the relative values of land for water resources. These maps allow potential protection areas to be identified, according to risk and benefit.

By overlaying and integrating this information, it is possible to prepare maps showing land with the highest value for water resources, and thus indicative areas for environmental protection. This Technical Guideline details the aims and methods for the preparation of indicative watershed management zoning.

2.6 Step 6: Prepare an Indicative Zoning Map for Air Quality Protection

The analysis of air quality across the UREMP Area will enable maps to be prepared showing capacity for further urban development, areas where air pollution must be prevented and/or reduced, and the contribution that natural areas can make to improving air quality in cities. These areas are represented as various zones on the indicative airshed zoning maps, to be overlaid on the other indicative zoning maps to allow the identification of land with the greatest need for environmental protection.

2.7 Step 7: Prepare an Indicative Zoning Map for Ecosystems Restoration

Potential renewable energy resources are distributed unevenly across the landscape. Biomass, as an energy resource, can be a by-product or primary output of very different natural, farmed and created environments. Hydropower potential is confined to specific combinations of rainfall and topography. Wind energy is the result of climatic and topographical factors at both the macro and micro scales. Solar radiation is affected by microclimate, slope and aspect. Geothermal energy is determined by variations in local geology. Where these factors combine with forests, farmland, coastlines and other non-urban land, they become significant components in a holistic assessment of environmental values.

Where there is good evidence, maps of renewable energy resources that show areas of high potential provide important input to the assessment of environmental values. The relative value of sites for renewable energy generation is not likely to be so great that they justify the protection of those sites for these reasons alone, but combined with other values – for instance, forests and biomass, or coastlines and wind power, or farmland and solar power stations – considerations of renewable energy may determine which areas are zoned for environmental protection.

In Step 7, maps for renewable energy potential are overlaid and integrated, to arrive at indicative energy zoning map(s), to be overlaid with maps from the other steps. This Technical Guideline details the methods and procedures to analyse renewable energy potential and to prepare the indicative energy zoning map.

2.8 Step 8: Integrate all outputs in an Environmental Protection Zoning Instrument

The two operative UREMP environmental protection zones, red line and yellow line (the green line is the remainder and requires responsible development) are compiled on layers of comprehensive analyses, each leading to many more than just two protection zones.

Any one Step – for instance, Step 4: Prepare an Indicative Zoning Map for Green Land Protection, generates many layers of analysis – in this case, forests, agriculture, mineral resources, etc – which might distinguish between different kinds of forest lands, or different environmental impacts of agriculture, or different environmental sensitivities. The resulting indicative zones for non-urban Green Land will show a range of assessments concerning the environmental value of distinct areas of land, and a range of potential policy responses (no development of any kind, certain kinds of positive development, encouragement of rehabilitation, long term protection for future purposes, etc.).

Each of Steps 3, 4, 5, 6 and 7 will generate an indicative zoning map of this kind, with a range of assessments and policy responses depending on a number of spatial and non-spatial factors.

To give another example, Step 5: Prepare an Indicative Zoning Map for Water Quality Protection. There will be layers of analysis – rivers, lakes, wetlands, coasts, water source protection, etc. – identifying the attributes and values of specific land or water according to its condition and its potential role as a protected area. These will be merged into indicative zones for water quality protection, zoning land in a variety of ways according to its value for particular purposes.

This is a complex but essential process. It results in six *indicative zoning maps* generated by Steps 3, 4, 5, 6 and 7. By overlaying the six maps, areas with exceptional value, and areas with high values for a number of sectors, and areas with potential to provide essential environmental services, become candidates for the red line environmental protection zone. The analysis leading to this result must be interpreted alongside the red line, since the reasons for including each specific land and water area might be quite different. In short, land and water areas in the red line zone are not all the same. They are all to be given the highest level of protection from development, but for possibly diverse reasons.

The logic of the yellow line is different. While areas of land and water in the yellow line zone do not justify the blanket ban on development provided by the red line environmental protection zone, they are protected in specific ways depending on their attributes and the impact that various kinds of development would have on their environmental values and functions.

Accordingly, the yellow line zone is differentiated, with different policy implications in different areas. In some parts of the yellow line zone, low-impact urban development is compatible with environmental protection; in other parts, forms of green development such as farming or recreation is compatible; in yet other parts, the construction of certain kinds of infrastructure may have little impact, or may be beneficial.

This Technical Guideline details the aims, methods and procedures for the preparation of a UREMP environmental protection instrument with a red line zone and a yellow line zone.

3 The Technical Modules in Step 1: Establish the UREMP Area and Partnership

3.1 Significance

City is not isolated and enclosed, and there is certain fluidness of materials in the resource, environmental and ecological systems in areas between cities, between city and village and between city and a larger scale area. In other words, diffusion exists in the transmission of pollution. On the one hand, urban pollutant resources and the followed environmental problems may be due to external influences; on the other hand, the environmental problems and pollutant discharged within the cities may also have certain influences on the other areas.

As UREMP is a planning for solving the structural environmental problems at root cause based on natural laws and the characteristics of ecological system. Therefore, for UREMP, the area coverage affecting the resource and environment system should be firstly determined, and the impact scope of the urban/township resource and environment system to other areas should be determined secondly. The environmental problems can only be solved fundamentally by taking natural laws of transmission and clearly determining the scope of research.

However, as the environmental management system of China determines that the environmental problems should be solved by "jurisdiction authorities", solving environmental problems still depends on administrative mechanisms. Therefore, the determination of research scope of UREMP and management model of implementation should also take into account the administrative system, to determine the scope and boundaries of UREMP.

Approach

I. Clear delineation of urbanized area. Due to different urbanization progress between urban and rural areas, determination of planning goals, formulation of environmental protection strategies and other goals should be in alignment with the level of urbanization.

II. Determination of environmentally affected scope and the environmentally affecting areas. Research on the scope and boundaries affecting the urban resources and environment system, as well as the boundaries it affected should be carried out from the perspective of regions, basins and urban and rural areas.

III. Analysis of the boundaries of biodomians and biosubdomains. The spatial distribution of ecological system in the regions should be analyzed to determine the ecological functions of different regions and the boundaries of biosubdomains.

VI. Comprehensive determination of boundaries of planning by taking into account the administrative system.

Delineation of urbanized areas

The urbanized areas and potential areas of urbanization should be clearly determined by taking into account the basic situation of the areas and the urban development characteristics, so as to scientifically develop the goals of stage development of "living friendly" and "easy living" cities, as well as its development boundaries.

The information and data needs to be prepared includes: present urban land use map, urban-rural master planning drawing, master planning of land use.

Contiguous areas of existing construction land, key development areas specified in urban-rural master planning, land specified in land use master planning for urban and township construction and other important areas for future urban development, as well as the urban and rural scopes should be delimited into different levels in accordance with the levels of urbanization.

Determination of scope of the environmental impact

The air and water environment systems should be analyzed from the perspective of basins and regions, to clearly determine the scope of areas affected by the pollutant transmission of urban-rural environment.

Key tasks need to be carried out include: simulation of 3D flow field of air environment, analysis of generalization of water system and analysis of influence of transmission of water pollution. The concrete simulation process and relevant data is detailed in the control of air and water environment space control and will not be covered again hereby.

(1) Determination of the scope of influence of air environment

Simulation of 3D flow field of air environment should be carried out, extending the research scope to surrounded neighboring counties, urban clusters and provincial region, to simulate the characteristics of air environment at different scales on mainly two factors of direction and speed of the wind. Based on the result of simulation, identify the scope of area has certain influence on regional air environment and the scope of area affected by the regional air environment quality. See STEP 6 for the detailed process of simulation.

(2) Determination of the scope of influence of water environment

The scope of research should be extended to the up and down streams of the water system of the city/town, and generalization analysis should be carried out to the water system, to analyze the transmission path of water pollutant, the certain scope of upstream regions that will affect the water environment quality of this city/town, as well as the certain scope of downstream region that will be affected by the discharge of water pollution of this city/town. See STEP 5 for the detailed process of simulation.

Determination of boundary of bioregions

The differentiation and variation characteristics of ecological system should be analyzed from the perspectives of integrity of ecological system and consistency of biodiversity, etc., and the regions that have relative consistency and certain relationship with the ecological system of this region should be incorporated into the research.

Key tasks need to be carried out include: analysis of integrity of the ecosystem, analysis of consistency of biodiversity and analysis of relevance of ecological corridor.

Data needs to be prepared: regionalization map of regional ecological functions, DEM data, vector data of physiognomic type, type of vegetation coverage and soil type, etc.

(1) For provinces that have finished the delimitation of ecological function zones

As the Ministry of Environmental Protection has completed the national ecological function zoning, most provinces have completed the ecological function zoning. So the delimitation and identification of biodomains and biosubdomains can be carried out in accordance with national or provincial ecological function zoning. First, the type of ecological function zone and sub-zone should be determined; then, the scope of region covered by this type, namely the scope of regions that needs to be taken into account to maintain the integrity of the ecological system, should be determined.

(2) For provinces that have not yet finished the delimitation of ecological function zones

The cities that have not yet finished the delimitation of ecological function zones are recommended to adopt the following methods to identify biodomains and biosubdomains:

Identification of bioregions:

Taking the landform factor of the natural environmental factors as main factor, based on the special details of specific cities, elements such as ratio of Pingba area, ratio of tableland areas, ratio of hill land areas, ratio of low height mountain areas, ratio of medium height mountain areas, ratio of mountain plain areas, ratio of water surface areas, etc., should be chosen to carry out clustering analysis, and the regions maintaining the similarity of regional climate characteristics and the integrity of landform units should be delimited as a complete bioregion.

Delimitation of subregions:

Based on the types of ecosystems and the types ecological service functions, the integrity of types and process of ecosystems within the region should be maintained, and the consistency of the types of ecological service functions should be also taken into account. It is recommended to choose different indicators based on the characteristics of the urban ecosystem, to carry out cluster analysis and principle component analysis, so as to delimit the region with relative integrity of ecosystem type and relatively consistent ecological service function types into a same subregion.

The indicators recommended are shown as follows:

① Natural condition indicators of characteristics and service functions of ecosystem.

Include: ratio of farmland in all land area, ratio of low height mountain areas, ratio of medium height mountain areas, ratio of farmland areas with steep slope larger than 25° in all farmland areas, forest coverage and capita amount of water resources, etc.

② Indicators of socio-economic development

Include: population density, urbanization rate, per capita GDP, etc.

③ Ecological environment status indicators

Include: air pollution index, water pollution index, soil erosion modulus, etc.

④ Comprehensive indicators of ecological sensitivity

Based on the grading result of evaluation of ecological sensitivity (sensitivity of soil erosion, acid rain sensitivity and rocky desertification sensitivity), 0, 0.25, 0.5, 0.75, 1.0 should be weighted to the five levels of insensitive, mild sensitive, moderately sensitive, highly sensitive and extremely sensitive, so as to obtain the comprehensive indicators of ecological sensitivity by taking into account the areas of the sensitivities. The concrete evaluation processes and methods are in Step 3.

3.2 Module 1A: Map the boundaries of bioregions and subregions

This is one of two essential first tasks: to describe and document the basic characteristics of the natural environment in the regions where a UREMP Area may be defined. Note: bioregions and subregions are higher-order divisions and may overlap the diverse ecosystems and landscapes mapped in Step 3. The term bioregion, rather than biodomain, reflects the scale of the spatial units being considered. See Ni Jian, Chen Zhong-Xin, Dong Ming, Chen Xu-Dong and Zhang Xin-Shi. An Ecogeographical Regionalization for Biodiversity in China. *Acta Botanica Sinica* Volume 40 Issue 4, Pages 370-382.

In the relevant sciences there are many classifications for spatial distributions within the biosphere, including for distinct biological complexes, types of territories, types of land cover, and landscapes, generally in hierarchies from global down to single sites and elements. Ecosystem management has generated many overlapping schemes for stratifying the earth into progressively smaller areas of increasingly uniform environmental characteristics.

In this regard, key concepts for UREMP include the following.

- **Bioregion**: Bioregions are large, geographically distinct areas of land with a unique overall pattern of natural characteristics including a particular climate, a local pattern of seasons, specific landforms and soils, watersheds, and populations of native plants and animals.
- **Biosubregion**: A bioregion will divide into a number of more uniform subregions, all of which are fully contained within the one bioregion. There is greater similarity in natural characteristics within than between each subregion. Bioregions and subregions are mapped in Step 1.
- **Ecosystem**: A complex of living organisms with their (abiotic) environment and their mutual relations. A practical approach to the ‘spatial delimitation of an ecosystem’ is to build up a series of overlays of significant factors, mapping the location of discontinuities: a useful ecosystem boundary is the place where a number of these relative discontinuities coincide. While ecosystems can be described at all hierarchical levels (from the Earth’s biomes to a single water drop with its microorganisms), for the practical purposes of mapping, assessment and policy in a UREMP Plan, ecosystems have the scale of habitat/biotope or landscape. Ecosystems are mapped and assessed in Step 3.

Classifying space into bioregions and subregions is essential for UREMP, but a pragmatic approach is also essential.

- UREMP is an administrative activity for regulating human activity in the interests of protecting the environment: it is not primarily a research activity aimed at creating new knowledge, and to have immediate effect it must rely primarily on existing data.
- UREMP must be able to generate policy and practical measures for the regulation of human activity (primarily urban development) and should therefore avoid purist or exhaustive approaches to classification, and instead adopt *spatial units* that are relevant to *existing planning instruments* including urban and regional strategies, master plans and detailed development plans.

The outputs from Module 1A are maps and supporting information describing the bioregions and subregions in the potential UREMP Area and surroundings areas. This documentation should be done in a form that can be included in the UREMP Atlas and database (see Step 2).

3.3 Module 1B: Map urbanized areas and areas exposed to risk from urban and suburban development and sprawl due to proximity and/or planning

This is the second of the two essential first tasks: to *describe* and document urban and development pressure in the regions where a UREMP Area is to be defined.

The aim of Module 1B is to map urbanized areas, potential areas of urbanization and future directions of urban, industrial, infrastructure and other development, based on land use maps, urban and regional strategies, urban-rural master plans, land use master plans, and other relevant data for all the areas considered in Module 1A.

The outputs from Module 1B are maps and supporting information describing present and future urbanisation and other development, and the pressures on the natural environment, in the potential UREMP Area and surroundings areas. This documentation should be done in a form that can be included in the UREMP Atlas and database (see Step 2).

3.4 Module 1C: Document and adopt objectives, controls and evaluation standards and methods

The revised Environmental Protection Law of the PRC governs the potential scope of UREMP and UREMP Plans. This report (including Sections 1.3 and 2.1.5) shows that the existing system of environmental standards and controls in the PRC creates a sound foundation for UREMP, and provides opportunities for effective local measures for environmental protection.

The State Council sets pollutant emission control targets to be implemented by provinces, autonomous regions and municipalities. MEP issues environmental quality standards with limits on the concentration of hazardous substances and the discharge of pollutants. These can be supplemented by standards adopted by governments above the level of municipality. Standards to be enforced by municipalities can be set by provincial governments in separate or joint UREMP Plans.

While there are many environmental policies on the pollution of water and air, not all ecosystem services are currently covered by standards. UREMP Plans with provincial partners will be able to establish local and regional quality standards and threshold values for all environmental media. Where national total-amount limits have been set, these UREMP Plans will also be able to scale down the targets to lower levels including provinces, districts and local industries. UREMP Plans with provincial partners will be able to extend total-amount control policies to urbanization rates, green-house-gas emissions, nitrate surplus, no-net-loss of biodiversity and organic soil, no-net-loss of farmland and forest, etc.

All of these matters, and many others, define the potential scope and powers of a UREMP Plan as well as its limits. The objectives, assessment principles, assessment methods, standards, limits and restrictions, to be applied in a UREMP Plan, need to be documented and, where applicable, mapped. This documentation should be done in a form that can be included in the Atlas and database (see Step 2).

3.5 Module 1D: Agree on jurisdictions and UREMP partnership

Where the proposed UREMP Area covers multiple jurisdictions, the aim of Module 1C is to form effective partnerships among the provinces, municipalities, counties, districts and agencies within the proposed area. To organize the process of a UREMP, partnership agreements need to be agreed, a UREMP steering committee and working groups need to be established, roles and responsibilities need to be negotiated, and a work plan to effectively carry out a UREMP Plan needs to be adopted. The options for legal arrangements, institutional frameworks and policy recommendations are discussed in *Report Three: Recommendations for Policies and Institutional Arrangements of UREMP*.

Achieving *integrated governance* will require cross-jurisdiction consultations and negotiations under the guidance of environmental protection experts and with observation and leadership from higher level governments to set an adequate extent and scope for the proposed UREMP Plan. Where jurisdictions do not join a UREMP partnership, they may still be needed in partnerships to address specific environmental problems.

The jurisdictions within the UREMP Area will need to agree to translate the resulting UREMP environmental protection zones into their environmental protection plans, informing their master development plans, land use plans, housing programs, infrastructure programs and urban design plans.

The outputs from Module 1D are enduring *agreements* and decision making *structures* and processes to prepare and implement the UREMP Plan. Documents and data relevant to the preparation of the UREMP Plan should be done in a form that can be included in the UREMP Atlas and database (see Step 2).

3.6 Module 1E: Agree on the boundary of the UREMP Area

The aim of Module 1E is to agree on a final boundary of the study area for the UREMP Plan among the jurisdictions that formed the UREMP partnership in module 1D.

On the basis of the mapping of natural systems and present and future urban impacts, and on the basis of the agreements reached in Module 1D, the precise boundaries of the UREMP Area are defined, confirmed, and included in the UREMP Atlas (see Step 2).

3.7 Example

3.7.1 Example from Fuzhou

Delineation of urbanized areas.
There are five central urban divisions in Fuzhou including Jin'an and Mawei, etc. According to the overall urban development strategy of Fuzhou, it will actively implement the "Big Fuzhou" strategy to promote urban development in a way of "along the river and facing the sea", and the Changle City will serve as an important expansion region of central urban area in the future. Therefore, other than the five central urban divisions, Changle will be incorporated into key region of urbanization in the UREMP of Fuzhou; the whole administrative region of Fuzhou will be delimited into three levels of central urban region, planning region and municipal region according to the different orders of urbanization. Environmental protection strategy should be formulated in accordance with the three different spatial scales for determination of planning goals and solving key problems.

Figure 3-7-1 Delimitation of urbanization region at different levels of Fuzhou

Determination of scope of the environmental impact

With the continuous expansion of Fuzhou and other cities at west bank of the Taiwan strait, and the contiguous urban development in the region, subjected to the dual role of atmospheric circulation and atmospheric chemistry, the interaction effect of air pollution between cities becomes significant, and the pollutant transmission influence between adjacent cities becomes gradually prominent. Taking into account the data of terrain and elevation, the WRF+CALMET meteorological models were adopted to simulate the three-dimensional atmospheric flow field of the west bank of the Taiwan Strait at a resolution of 3km. The result shows that, as the west bank is mainly dominated by the northeast wind, so Wenzhou, Zhejiang Province and Ningde, Fujian Province at the northeast direction have relative large influence to the air quality of Fuzhou; in the meanwhile, the air quality of Fuzhou will also affect that of Putian and Quanzhou and other cities in the south. Therefore, other than atmospheric environment, research on atmospheric environment related issues should also take Wenzhou, Ningde, Putian and Quanzhou into overall consideration.

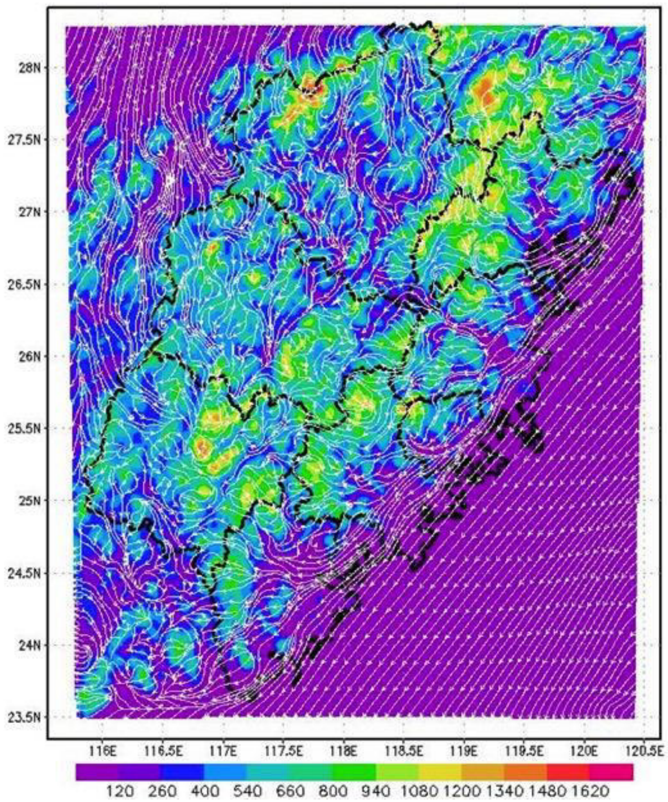


Figure 3-7-2 Result of Simulation of 3d Flow Field of Atmospheric Environment at West Bank of the Taiwan Strait

The three main rivers of Minjiang River, Dazhangxi River and Longjiang River in Fuzhou have relatively good water environment quality. The result of pollutant transmission analysis of water environment shows that, other than Mingjiang River, the regions of Dazhangxi River and Longjiang River with water quality affected are all in the administrative region of Fuzhou. Since Minjiang River is the largest single stream flowing into the sea (East China Sea) of Fujian Province, it flows over 50 km into the sea after passing through Fuzhou, so the water quality of up-stream of Minjiang River is relatively good and stable in the long run, therefore, the up-stream area will not be taken into consideration into the research for now, while the offshore area of Fuzhou will be taken into overall consideration in the research.

Determination boundary of biodomains and bioregions

According to the ecological function zoning of Fujian Province, the ecological function zoning of Fuzhou covers four biodomains of "medium and low height mountain area-low height hilly and valley basin-coastal tableland and hills-offshore area"; Fuzhou covers the types of ecological maintenance of water environment of sea and land areas and the ecological function zones mainly for serving urban development, etc., involving protection of fisheries and wetlands, maintenance of water environment and reservoirs and the landscape around them, the guarding of water quality of source of drinking water, etc.

The biosubdomain of coastal zone and off-shore area in east Fujian, the biosubdomain of coastal tableland and hill plain and off-shore area in southeast Fujian, as well as the medium and low height mountain plateau area in the east and middle Fujian are the three biosubdomains overlapped with neighboring cities. The biosubdomain of coastal zone and off-shore area in east Fujian and the biosubdomain of coastal tableland and hill plain and off-shore area in southeast Fujian have relatively significant functions of maintaining the off-shore ecology; from the perspective of ecosystem maintenance, the biosubdomain of the medium and low height mountain plateau area is closely related to the ecosystem of Fuzhou. Furthermore, given the consistency of the overall topography, in the biosubdomian of the medium and low height mountain plateau area, Putian, west Quanzhou and Fuzhou are all in the Jiufeng Mountain-Daiyun Mountain chain, and they are the first barrier for the maintenance of mountainous ecosystems in southeast China. Therefore, for the research on ecosystem related issues, in addition to Fuzhou, adjacent cities of Putian and Quanzhou are included in the research.

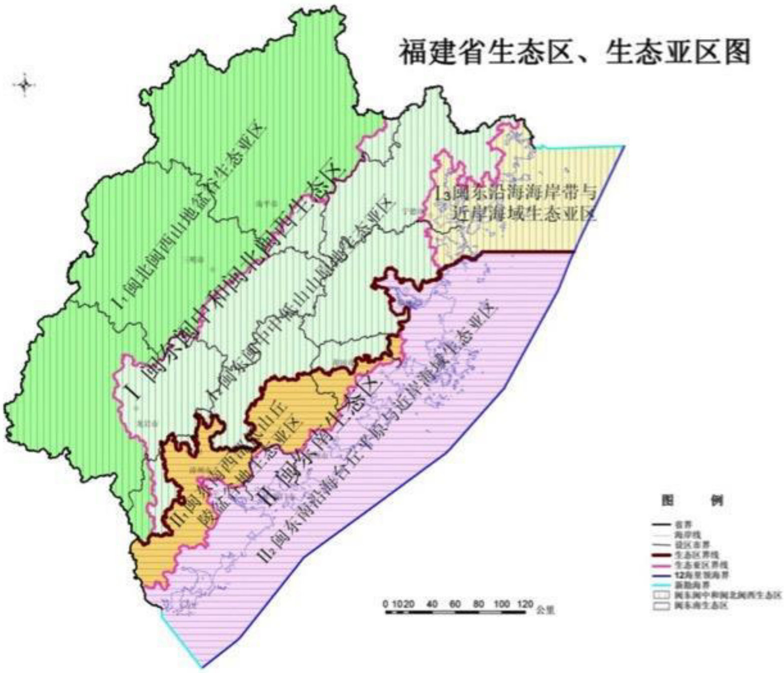


Figure 3-7-3 Biodomains and Biosubdomains of Fujian Province

Determination of boundary of comprehensive research

Based on the above analysis, overlapping the urbanized regions, atmospheric environment affected scope, water environment affect scope and boundary of biodomains, taking into account the linkage of environmental management, the boundaries administrative divisions are selected and adjusted, to determine the boundary of comprehensive research of UREMP of Fuzhou. Other than the whole administrative region of Fuzhou, the boundary of comprehensive research also covers Ningde in North Fuzhou and Putian and Quanzhou in South Fuzhou.

4 The Technical Modules in Step 2: Prepare standards for the UREMP Atlas

4.1 Purpose of this Guideline

Step 2 is concerned with process and format rather than content: shared standards for collecting and managing data, agreed ways to manage geographical information systems (GIS), and a common format for maps. These standards are essential if the data collected by many agencies is to be accessible, comparable, integrated and kept up to date. It is also essential if all the data and spatial information for the UREMP area is to be integrated in the UREMP Atlas.

The UREMP Atlas is not a document or a publication. It is an emerging network of internet databases, owned and maintained by the agencies which collect and update the data and maps, with rights of contribution, editing, analysis and access assigned to various entities according to the protocols and procedures agreed by the UREMP partnership.

Objectives

Studied the mapping norm of UREMP with standard uniform through determining the mapping content system, expression form, coordinate system requirements and so on, to promote the technical support for promoting the connection between the UREMP with other planning, implementing of UREMP, and space to the ground, and also to provide guarantee for the organization and implementation of UREMP.

It is an urban environment Master planning business whole-process management platform which can realize effective management and multi-level shared application services on urban environment infrastructure spatial information resource, business flow and spatial data integration, network technology and mobile terminal application integration, and no threshold of application technology aiming at whole urban ‘one-map’ management demand of a digital city.

The network management systerm mainly includes planning result management system, planning project management system, planning space analysis and management system, planning surveillance system and planning business approval system. Data management, image editing, spatial analysis, spatial query, mapping, data transformation and metadata management functions are provided.

4.2 Module 2A: Adopt data standards

The **objective** is to establish a shared data management and agree on data standards and protocols among the local governments and agencies within the UREMP areas.

Methods include review of currently used data formats and standards in the jurisdictions and analyse national and international best practices and establish a robust and widely compatible set of standards for instance covering metadata and thesaurus, data quality requirements and quality assurance measures. The basic principles should include sharing, ready access, maintenance by the provider, and adherence to common standards.

Data standards

All the data provided should indicate the source, accuracy and timeliness, and strive to cover all jurisdiction. The accuracy of spatial data should be more precise than 1:100,000.

All the spatial data should be provided in vector format. The image should can be vectored by GIS with high resolutions.

Coordinate projection requirements: the plan coordinate system of formal map adopts “1980 Xi’an coordinate system”; Elevation system adopts “1985 national elevation datum”; Projection system adopts Krueger Gauss projection; 3° zoning is better.

Principles of access to data and maintenance of data

Basic principles include data sharing, data access, maintenance of provider, adhere to the common standards.

In order to achieve the data sharing between environmental protection system, public and project applicant, provide more effective services on the network. The following are some requirements and standards of UREMP atlas.

(1) Planning Result Management System

①It shall at least include four major planning results of UREMP planning outline, planning text, planning study report and planning atlas.

②It should include urban planning, land use Master planning and other planning results atlas, thereby realizing integration of many plans.

Users include EPA, Planning Bureau, Land and Resources Bureau and other planning departments.

(2) Planning Project Management System

①Subsystem of planning project should include all details to support the project in planning support design. (2) Subsystem of control project includes project lists that should be relocated in red line area, guidance and limitation of project type layout in yellow line area.

②Subsystem of environment statistics enterprise is associated with real-time monitoring equipment of all environment statistic enterprises.

User includes EPA.

(3) Planning Spatial Analysis Management System

Graphic editing, spatial analysis, spatial query, mapping, data conversion and metadata management functions of base map and all planning elements can be realized, and user is EPA.

(4) Planning Surveillance System

Planning results, newly-established project and reformed project can be approved, original project control requirements should be disclosed, and the operator can log in for inquiry through mobile equipment, and the user is the public.

(5) Planning Business Approval System

Application and approval of one-stop services and inquiry of related planned business are realized. Users should include project applicant and EPA.

①It should include system management, project declaration, automatic initial inspection, comment reply, project query and other modules, thereby serving construction unit, clerks in bureau, business personnel and technical review staff.

②It has functions of user registration, project declaration, plan uploading, automatic initial inspection, comment reply, program modification, result query, etc.

Mechanisms to drive harmonization and interoperability

Achieving interoperability and the harmonization of data may be challenging and requires significant commitment of time and resources, driven by a high-level interagency task force. The known rule, however, is that this work needs to commence at the beginning of the UREMP process, and needs to be sustained over the entire life of the UREMP preparation and maintenance periods.

The task of data collection is heavy, which needs actively cooperation with multiple departments. Therefore, in order to collect data more efficiently, the local EPA should appoint one personnel to collected data and connected with other bureaus, and he should be responsible for docking with data matters. Meanwhile, once UREMP begins, the mayor or vice mayor who administrated EPA in local city should hold a mobilization meeting for UREMP, to mobilize other bureaus to provide key needful information for UREMP. During the meeting, the list of data requirement should be sent to the bureaus representatives, and their approval is better to be obtained just in the meeting.

Due to the process of drawing red line involves many legal reserve areas. Therefore, we proposed to put boundaries of these legal reserve areas as the focus of data interaction. If boundaries of these legal reserve needs some adjustment, the relevant bureaus should notifies the contactor of EPA timely, and then to planners, to guarantee the timeliness and accuracy of all the data used in UREMP.

After drawing the red line, the opinions of relevant bureaus also should be collected constantly, to make sure all the resources were up-to-date.

4.3 Module 2B: Adopt GIS standards

The **objective** of this module is to develop and agree on a common GIS system and platform and base mapping system that will serve as the main tool for spatial analysis and mapping.

Methods include review of current practices in the concerned jurisdictions and agencies and stakeholders, assess national and international best practices, and develop and agree on a common system for the UREMP. The benefits of a robust GIS system and platform will be critical for the effective UREMP development and maintenance. The roles and responsibilities of data coordinator, data integrator, data provider and data consumer will need to be defined and issues of content for instance the categories of data to be maintained, software etc. need to be agreed upon.

Suggested GIS platform and other software

The mapping of UREMP can use GIS, MAPGIS, AutoCAD, Illustrator Adobe, Photoshop, InDesign and other software. In addition, Office, SPSS, ORIGIN, and etc., can be used in the data analysis.

Recommended categories of data

The categories of data including vector data can be used by GIS or CAD, Office text, and pictures in JPG. The following data should cover the entire planning boundary, and should be the latest data.

Table 4-3-1 Recommended categories of data

Number	Data types	Recommended categories
1	Land use data	Vector data
2	Remote sensing image	Vector data
3	DEM	Vector data
4	Distribute of Soil type	Vector data
5	Soil properties	Soil species book of local government
6	Key risk sources	Excel(include information such as latitude, longitude, risk, risk, etc)
7	Boundary of River, lake, wetland, etc	The related protection planning text, map(vector data is better)
8	Biological diversity, habitat	The boundary of related protection district (vector data is better)
9	Brownfield	Provide the name list, the latitude and longitude, and the other relevant information of the brownfield, or map
10	Greenland	The boundary of Greenland (vector data)
11	Populations	The populations of each township and town
12	Flood control area	Provide flooded area, flood storage and detention basins, and protected area boundaries (vector data)
13	Atmospheric monitoring data	Provide 10-year average meteorological data (monthly, annual average temperature, precipitation, evaporation, sunshine hours, mean sea level pressure, average wind speed, wind direction and frequency, cream, number of days of fog, the wind rose diagram)
14	Meteorological disaster	Temporal and spatial distribution of meteorological disasters (vector data)
15	Geological hazard	Temporal and spatial distribution of Geological hazard (vector data)
…	…	…

Roles of data coordinator, data integrator, and data provider

Data Coordinator is the designated staff from Environmental Protection Bureau. Data coordinator is responsible for the data collection in the planning process. And also if the collected data has been updated, the data coordinator should be in a timely manner to notify the planner to update the planning results.

Data integrator is generally from the planning establishment unit and a professional data processing personnel. Data integrator is responsible for the collected data and analysed them, space falls to the ground, adjust the boundary, establish a database, generate and modify planning maps, update the planning results. At the same time, the data integrator, who have signed the data confidentiality agreement under the confidentiality requirements of data provider, should be carefully implemented the confidentiality agreement. And after planning establishment work is finished, all the related data in the planning process should be packaged to EPA.

Generally, data providers are from EPA or other relevant bureaus, such as bureau of land and resources, planning bureau, water conservancy bureau, forestry bureau, tourism bureau, oceanic bureau, etc. The authenticity and timeless of data resources should be guaranteed by data providers. If some confidential data should be provided, data integrator needs sign a confidentiality agreement. During the compilation or implementation process of UREMP, if the data resources changes, data coordinator should be notified.

Data users are EPA, project applicant and public. Data users have the right to query the quality, timeliness, etc. of data resource, and get feedback from planners or EPA. The project applicant and the public encounter any problems during the process of using the platform developed by planners, can consult from planners or EPA.

4.4 Module 2C: Adopt mapping standards and base maps

Goals for the mapping work

The **objective** of this module is to clear the guidelines of building a collection of maps and a map atlas; the structure of the collection and the atlas including the definition of basic and thematic maps; a style guide for the map legends; and the format for the map layout.

Structure and themes of the UREMP Atlas

According to the content requirements of UREMP and the pilot city environmental protection planning drawing list, 72 pieces of drawings should be designed totally.

According to the drawing properties, the drawings are divided into status drawings, analysis drawings and planning drawings, among them there are 25 pieces of status drawings, 16 pieces of analysis drawings and 31 pieces of planning drawings.

According to the necessity of drawings, the drawings are divided into basic drawings and recommended drawings, among them there are 31 pieces of basic drawings and 41 pieces of recommended drawings.

According to the expressed scope of drawings, the drawings are divided into planning scope, area, city center, key areas, etc.

Meanwhile, according to the expression content of drawings, the drawings can be divided into basic class, atmospheric environment, water environment, ecological environment, Environmental restoration, renewable energy, electromagnetic radiation, environmental monitoring, etc.

1) Status Drawings

Status drawings are divided into basic drawing, atmospheric environmental status drawing, water environmental status drawing, ecological environmental status drawing, status drawing of electromagnetic radiation, status drawing of environmental monitoring network, totally 25 pieces of drawings, among them there are 11 pieces of basic drawings and 14 pieces of recommended drawings.

2) Analysis Drawings

Analysis drawings are divided into basic analysis drawing, atmospheric environmental drawing, water environmental drawing, ecological environmental drawing, totally 16 pieces of drawings, all of them are recommended drawings.

3) Planning Drawings

Planning drawings are divided into atmospheric environmental drawing, water environmental drawing, ecological resources drawing, drawing of environmental monitoring network, ecology system protection map, Green Land protection map, ecology restoration map, and comprehensive drawing, totally 28 pieces of drawings, among them there are 10 pieces of basic drawings and 18 pieces of recommended drawings.

Table 4-4-1 Status drawing list

Code	Type	Name	Properties	Expression content
1-1-1	Basic drawing	Regional location map	basic	City location and surrounding traffic.
1-1-2		Administrative map	basic	Jurisdiction boundaries and administrative center divided by different levels of administrative departments in the city center, set colors by administrative jurisdiction division, which can appropriately express river system, road traffic, residential areas, etc., and reflect the relation between administrative regions.
1-1-3		Planning boundary map	basic	According to the content requirement of UREMP, determine the scope boundary and the partition of planning, meanwhile, the city centre and city boundary should be expressed.
1-1-4		Remote sensing image	recommended	Distribution of forest, town, water, farmland, saline-alkali land, paddy field, beaches, marine and other ecological environmental elements among regional scale through remote sensing image.
1-1-5		DEM	recommended	Altitude of planning scope.
1-1-6		Landscape type map	recommended	Relief degree and distribution of landmark component material.
1-1-7		Distribution map of stream	recommended	Water network system of all rivers , lakes, reservoirs and other water bodies.(need to label the source of water)
1-1-8		Land use status map	recommended	Utilization of land resources, regional difference and classification.
1-1-9		Population density map	recommended	Population density.
1-1-10		Economic density map	recommended	Economic development level.
1-2-1	Atmosphere environmental drawing	Key atmosphere pollution source map	basic	Main coal-fired facilities, state key monitoring enterprise, pollution census industrial enterprise and other fixed point space layout.
1-2-2		Quality of atmosphere environment	basic	Spatial pattern of SO_2, NO_2, PM10, PM2.5, ozone and other main atmospheric pollutants' emissions.
1-2-3		Atmospheric flow map	recommended	Spatial distribution of the airflow movement at different seasons. (content may include dominant wind field characteristics of specified month, spatial distribution of annual leading wind field, spatial distribution of annual wind speed)
1-2-4		Distribution map of API	recommended	Several kinds of air pollutant concentration by using a convention detection simplified as a single conceptual index, the scope of air pollution and air quality condition are hierarchically expressed.
1-3-1	Water environmental drawing	Critical sources of water pollution	basic	Space layout of key sewage companies, sewage treatment plant, discharge outlet.
1-3-2		Spatial pattern of water pollutant	basic	Status map of spatial pattern of river, lake, reservoir water pollutants such as COD, ammonia nitrogen's emission.(monitoring cross section's location can be marked)
1-3-3		Status map of	basic	Status of surface water's main pollutants

Code	Type	Name	Properties	Expression content
		Surface water quality		such as the concentration of TP and ammonia nitrogen.(classification with reference to the surface water environment quality standard)
1-3-4		Status map of groundwater quality	basic	Status of groundwater's main pollutants such as the concentration of ammonia nitrogen, chloride, total coliform bacteria, etc.(classification with reference to the surface water environment quality standard)
1-4-1	Ecological environmental drawing	Distribution map of protected area	basic	Spatial layout of nature reserves（including wetland, wildlife reserve）, scenic areas, national forest park, the world natural and cultural heritage, etc.
1-4-2		NDVI	recommended	Using normalized difference vegetation index to express vegetation growth status, vegetation coverage, etc.
1-4-3		Status map of soil erosion	recommended	Using soil erosion intensity to express different types of soil erosion characteristics and the law of regional differentiation. (reference to the soil erosion classification standard)
1-5-1	Electromagnetic radiation	Status map of radiation source	recommended	Distribution of numbered and registered radioactive source.
1-5-2		Distribution of function density	recommended	Downtown radiation power density in different periods.
1-5-3		Risk source distribution of high pressure equipment	recommended	Location of downtown substation, power station, transformer and other high voltage equipment.
1-6-1	Environmental monitoring	Status map of Environmental monitoring section (point)	basic	Status of Ambient air, dust precipitation, river, drinking water, noise, electromagnetic radiation, soil environmental and other monitoring points' layout.

Table 4-4-2 Analysis drawing list

Code	Type	Name	Properties	Expression content
2-1-1	Basic analysis map	Urban expansion analysis chart	recommended	Express the process of urban expansion
2-1-2		Urban heat island distribution map	recommended	Express urban surface temperature distribution
2-1-3		Sensitivity evaluation map of soil erosion	recommended	The sensitivity of soil erosion can be divided into four categories, which are not sensitive, sensitive, low sensitive and highly sensitive.
2-1-4		assessment map of black land degradation	recommended	The thickness, erosion rate and corrosion time of black soil
2-1-5		Evaluation of water conservation importance	recommended	The importance of water conservation, mainly including the water conservation function and water conservation requirements, can be divided into three categories: No, medium and very important.
2-1-6		Evaluation of geological environment sensitivity	recommended	Sensitivity of geological environment, which reflects the influence of the geological disasters such as landslides, debris flow, etc.
2-1-7		Evaluation of acid rain sensitivity	recommended	Acid rain sensitivity, can be divided into four categories: not sensitive, mild sensitivity, sensitivity and highly sensitive.
2-1-8		Land suitability evaluation	recommended	The suitable of land on city development can be divided into five categories, which are very suitable, suitable, and should not be constructed, and cannot be constructed

Code	Type	Name	Properties	Expression content
2-2-1	atmospheric environment	Zoning map of atmospheric environment sensitivity	recommended	Drawing according to the function and the atmospheric flow field, and this map can be marked by atmospheric monitoring point
2-2-2		Distribution of atmospheric pollutant concentration forecast	recommended	Spatial distribution of prediction concentration of SO_2, NO_X, PM_X
2-2-3		Environmental capacity analysis of air pollutants	recommended	Spatial distribution of environment carrying capacity of SO_2, NO_X, PM_X
2-3-1	Water environment	Comprehensive evaluation of water environment	recommended	Drinking water source areas and their sensitive areas (grade), inland waterways and their vulnerable areas, coastal areas and vulnerable areas, etc.
2-3-2		Function adjustment of critical water catchment area	recommended	Catchment area, drink water source protection area, an important water catchment area land use including farmland, woodland, grassland, water area and urban land and unused land.
2-3-3		Spatial distribution of water pollutant emissions forecast	recommended	Spatial distribution of the emissions forecast of COD and NH_4-N
2-3-4		Environmental capacity analysis of water pollutants	recommended	The environmental capacity of COD and NH_4-N in water environment and its pollution load, which can be expressed on the water environment control unit (which can be simultaneously labelled with the overload zone, the general area and the rich area).
2-4-1	Ecological resources	Evaluation of the importance of biodiversity conservation	recommended	The importance of biodiversity conservation (mainly considering 3 indicators: the priority of the ecosystem, the level of protection species, the proportion of the number of species)

Table 4-4-3 Planning drawing list

Code	Type	Name	Properties	Expression content
3-1-1	Atmosphere environment	Function zoning map of air quality	basic	According to the "environmental air quality standard (GB3095-2012)", divided into two categories: one category for nature reserves, scenic areas and other special protected areas, and the two category of residential area, commercial traffic residents mixed, cultural, industrial and rural areas.
3-1-2		Atmospheric environmental classification control area	recommended	The control area of atmospheric environment (which can be included three types of red lines: the layout, the gathering and the receptor, at the same time, the yellow line and the blue line).
3-2-1	Water environment	Water environment function zoning map	basic	Water environment function area planning, should include nature reserve, drinking water source protection area, fishery water area, industrial water area, agricultural water area and landscape recreation area, etc., at the same time, the monitoring section.
3-2-2		Water environment control unit	basic	Distribution of water environment control unit
3-2-3		Flood risk zoning	basic	The prohibited zone: the 5 year flood level below the area, not allowed to continue to develop. The restricted area: 5 years to 20 year flood areas, only allowed some of the necessary development. The development zone is allowed: above 50 year flood areas for development, but should be facility with flood defence infrastructure.

Code	Type	Name	Properties	Expression content
3-2-4		Coastal protection area	basic	The coastline and aquaculture protection zone needs to be protected in priority
3-2-5		Water environmental classification control area	recommended	Classification of water environment control area (including red line, yellow line and the green line, coastal city should draw marine environment hierarchical control map).
3-3-1	Ecological protection	Ecological function zoning map	basic	The spatial layout of regional ecological environment zoning management can be based on the relevant requirements and standards of *National Ecological Function Zoning*.
3-3-2		Ecological environment quality control map	recommended	The biological abundance index, vegetation cover index, water density index, land degradation index, pollution load index.
3-3-3		Zoning map of Ecological function protection area	basic	Ecological function zoning
3-3-4		Landscape spatial structure of landscape ecology	recommended	Spatial structure, spatial function, coordination function and dynamic changes of different ecosystems.
3-3-5		Carbon cycle policy map	recommended	A rapid and broad scan of land uses in the UREMP area that tend to be carbon emitters and carbon sinks, and an assessment of the relationship of these characteristics to the protection and remediation of non-urban 'green' land
3-3-6		Regional ecological system protection zoning	basic	The ecosystems zoning, integrated map of 3-3-1, 3-3-2, 3-3-3, 3-3-4, 3-3-5.
3-4-1	Green land protection	Forest priority areas	basic	The spatial distribution and hierarchical classification of forest, and its value evaluation
3-4-2		Agricultural priority areas	basic	Ranking of agricultural areas according to their positive and negative externalities, and the creation of agricultural policy maps
3-4-3		Mineral resource priority areas	basic	Identifying (i) the impacts of mining on the environment and also (ii) the opportunities for environmental protection and recovery that arise from mining
3-4-4		soil conservation priority areas	basic	The policy maps express the priorities and policies relating to soils
3-4-5		Priority hazardous areas	basic	The non-urban land which are used for productive purposes, or have potential to be used for productive and/or urban purposes, are constrained by being prone to earthquake, volcanic eruption, landslip, mudslide, rockfall, inundation, subsidence, and other hazards
3-4-6		'green' land protection zoning	basic	The indicative ecosystems zoning, integrated map of 3-4-1, 3-4-2, 3-4-3, 3-4-4, 3-4-5.
3-5-1	Ecosystems Restoration	potential for habitat and biodiversity regeneration	basic	The areas with potential for habitat and biodiversity regeneration, or contribute to, areas of high environmental value.
3-5-2		Potential for water bodies and riparian restoration	basic	Remediation, rehabilitation and restoration of waterways (rivers, streams, wetlands, lakeshores, beaches)
3-5-3		Potential for urban greening	basic	The functions and integrity of unused land with high environmental value

Code	Type	Name	Properties	Expression content
		and open space		
3-5-4		Potential for brownfield remediation	basic	The brownfield with high value on restoring biodiversity or to produce food and fibre
3-5-5		Environmental restoration zoning	basic	Integrated the map of 3-5-1, 3-5-2, 3-5-3, 3-5-4
3-6-1	Renewable Energy Resources Protection	Biomass generation and usage	recommended	Land areas that can be a reliable and ongoing source of biomass for energy production
3-6-2		hydropower generation potential	recommended	identified sites where there is potential for hydropower production, including at very small scales
3-6-3		wind energy generation potential	recommended	the negative effects of wind turbines on visual landscapes, birds, nearby residents, etc., and the positive values of renewable and distributed energy production
3-6-4		Solar energy generation potential	recommended	The land with high potential for solar energy generation
3-6-5		Geothermal energy generation potential	recommended	Areas of greatest geothermal potential should be considered for inclusion in areas protected from urban development
3-6-6		Renewable energy resources protection zoning	recommended	Integration of 3-6-1, 3-6-2, 3-6-3, 3-6-4, 3-6-5.
3-7-1	Comprehensive	Comprehensive environmental protection zoning	basic	A concluding environmental protection zoning map delineating environmental protection zones (red line), restricted development zones (yellow line) and development zones (green line) based on the sectoral assessments.

Suggested map format, styles, legends, etc

1) Suggested map format

(1) Geographical Base Map

Geographical base map mainly contains the following elements: administrative boundaries; government residence; road network; waters.

(2) Research of Important Water Category Mapping

①Thematic elements

Thematic elements generally include the follows: river order, waters, graded water sources, etc.

② Schema

Rivers at different grades can be distinguished with lines in blue gradient colour system. Meanwhile, water source of different grades can be distinguished with line boxes in blue gradient colour system. Appendix should be adopted as reference aiming at concrete schema.

③Map Layer Control

Graphic elements are organized and drawn in hierarchical mode. Map layer covering sequence from top to down is shown as follows: annotation, administrative boundaries, other basic geographic element and important water thematic mapping elements.

(3) Study of Land-use Mapping

①Thematic Elements

Thematic elements include the follows three major parts of agricultural land, construction land and unused land.

②Schema

Colours of various lands can be determined according to land use plan related mapping specification as reference, and appendix can be adopted as reference for concrete schema.

③Map Layer Control

Graphic elements are organized and drawn in hierarchical mode. Map layer covering sequence from top to down is shown as follows: annotation, administrative boundaries, other basic geographic element and important water thematic mapping elements.

(4) Study of Soil Mapping

① Thematic Element

Thematic elements generally include the follows: red soil series; brown soil series; cinnamon soil series; black soil series; chestnut soil series; desert soil series; moisture soil series; meadow and boggy soil series; paddy soil series; saline soil series; lithology soil series, soil inorganic contamination and soil organic pollution and other content.

②Schema

Schema filling colours of different soils can be determined with soil name as reference, dashed line frame can be used for representing soil polluted area, and different soil pollution types can be distinguished by frame filling line direction. Appendix can be adopted as reference for concrete schema.

③May Layer Control

Graphic elements are organized and drawn in hierarchical mode. Map layer covering sequence from top to down is shown as follows: annotation, administrative boundaries, other basic geographic element and important water thematic mapping elements.

(5) Study of Atmospheric Environment Mapping

①Thematic Element

Thematic elements generally include the follows: relevant air pollutant emission unit, monitoring facilities, distribution of pollutants, pollutant concentrations, atmospheric environment zoning and other contents.

②Schema

Square dot labels are used as schematic symbols. Different air emission sources and testing facilities are distinguished according to blue gradient colour system and different symbols. Appendix can be adopted as reference for concrete schema.

③May Layer Control

Graphic elements are organized and drawn in hierarchical mode. Map layer covering sequence from top to down is shown as follows: annotation, administrative boundaries, other basic geographic element and important water thematic mapping elements.

(6) Study of Water Environment Mapping

①Thematic Element

Thematic elements generally include the follows: water pollution source, water treatment unit, monitoring section, sub-water-quality River, sub-water-quality waters and other contents.

②Schema

Square dot labels are adopted as schematic symbols. Water pollution source, treatment unit and monitoring sections are marked according to different colour systems. Rivers and waters with different water systems can be distinguished with lines and faces in different colour system. Appendix can be adopted as reference for concrete schema.

③May Layer Control

Graphic elements are organized and drawn in hierarchical mode. Map layer covering sequence from top to down is shown as follows: annotation, administrative boundaries, other basic geographic element and important water thematic mapping elements.

(7) Study of Ecological Reserve Mapping

①Thematic Element

Thematic elements generally include the follows: water source distribution, water source conservation function area, water and soil conservation function areas, wind prevention and sand fixation function area, flood regulation and storage function area, ecologically fragile sensitive area, biodiversity conservation area and other contents;

②Schema

Relevant mapping standards are adopted as reference, and various reserves are determined with line frames in different colour systems. To determine all kinds of different colour frames protected areas. Appendix can be adopted as reference for concrete schema.

③May Layer Control

Graphic elements are organized and drawn in hierarchical mode. Map layer covering sequence from top to down is shown as follows: annotation, administrative boundaries, other basic geographic element and important water thematic mapping elements.

(8) Study of Ecological Red Line Mapping

①Thematic Element

Thematic elements generally include the follows: ecological red line control area, sub-element ecological protection red line area, atmospheric environment red line area and other contents.

②Schema

Red, yellow and green are used for representing different ecological red line control areas. Pure colour and dot marker line frames are used for representing sub-element ecological protection red line areas. Filling line frames and single colour blocks can represent different function areas of atmospheric environment red line. Appendix can be adopted as reference for concrete schema.

③May Layer Control

Graphic elements are organized and drawn in hierarchical mode. Map layer covering sequence from top to down is shown as follows: annotation, administrative boundaries, other basic geographic element and important water thematic mapping elements.

2) Styles and legend

(1) General requirements

①Master planning drawing of urban environment should be provided with the following elements such as figure title, figure surface, figure boundary, compass, proportion, scale, legend, signature, date of preparation, figure number, etc. Other elements also should be available in corresponding plan drawing according to related requirements of various plans.

②UREMP should have clear and artistic layout. Contents should be complete, accurate and legible.

③Figure surface of urban environment Master planning should cover full range of planned use, directly associated scope of surrounding land, and other planning content scope that should be contained according to specification.

(2) Research of Basic Geographic Element Drawing

①Administrative Boundaries

Administrative boundaries in graphic area should show township (town) boundaries. Names of surrounding adjacent administrative units are marked outside the graphic area administrative boundaries, and appendix can be adopted as reference aiming at concrete drawing requirements.

②Government Residence

Township government residence can be expressed maximally aiming at government residence in graphic area, and appendix can be adopted as reference aiming at concrete drawing requirements.

③Elevation Characteristic Points

Elevation characteristic points include mountains, peaks, ridge, highland, mountain passes, etc. in graphic area, and appendix can be adopted as reference aiming at concrete drawing requirements.

④Contour Line

Urban environment Master planning map-making is related to addable counter lines during environment monitoring data spatial distribution, including air pollutant concentration value contour line, water pollutant concentration contour line, elevation value contour line, groundwater level contour line, etc. Contour line interval unit can be selected according to different data types. The colour of contour lines can be determined according to the described value type, the colour of contour lines in the same type can be determined according to gradient colour system, and the appendix can be adopted as reference aiming at contour line drawing mode.

⑤Other Surface Features

Other important surface features can be selectively expressed according to the regional situation. Appendix can be adopted as reference for expressing important transportation facility drawings.

(3) Annotation

① Main annotation content (appendix can be adopted as reference aiming at concrete drawing requirements)

Names of county (district) and township (town) government residences;

Names of roads, railways, airports and ports;

Names of water facilities;

Names of rivers, lakes and reservoirs;

Names of nature reserves and scenic spots;

Names of e elevation characteristic points;

Elevation values, etc.;

Names of other important surface features;

②Font and Word Size

There should be at most four annotation font types in the same graphic document. Simplified characters can be used as Chinese characters in Chinese character annotation. Concrete conditions are implemented according to related standards promulgated by State Council.

Chinese character: Microsoft YaHei, Song typeface, equal - line face letters (in bold), regular script, italics and official script, we should give priority to Song typeface.

Western character: Times New Roman, Arial Black, we give priority to Times New Roman.

③ Annotation Word Direction

Word direction is generally positive aiming at residential area name, natural geographic name, description annotation and letters and number annotation, and the word head should be directed to north map outline.

④Annotation Arrangement

Level word column, vertical word column, echelon word column and buckling word column can be respectively adopted according to actual condition.

Level word column: ligatures of all word centers form one straight line from left to right, which are in parallel with south map outline;

Vertical word column: ligatures of all word centers form one straight line from top to bottom, which are vertical to south map outline;

Echelon word column: ligatures of all word centers form one straight line, which is obliquely crossed to south map outline. When the south map outline is titled in 45° and less than 45°. They should be annotated from left to right. When the outline is titled in more than 45°, words should be annotated from top to bottom.

Buckling word column: sides of all words are vertical or parallel to linear surface features, which can be arranged into word column according to linear bending.

⑤Annotation Word Interval

Annotation word interval refers to the distance among all words in one column of annotation, which is divided into three categories:

Close character: word interval is 0 to 0.5 mm;

Ordinary character: word interval is 1.0 to 3.0 mm;

Isolated character: word interval is 1-5 times of word size.

(4) Scale and legend

The scale should be located below the map frame, and mark the numerical ratio. Legend should be centralized layout in the left lower corner or the right lower corner of the map frame, and with the legend box definition. Legends should not cover the important planning information of the map.

International best practices

Australia has a long history of environmental planning, and a complete environmental planning system 'from top to down' is formed now. Its *local environmental plan* is the key legal documents, which is used to determine the land use, use of local-level development controlling or land use districts, standards of development, and provisions of other planning.

Taking *Local environmental planning in 2013 of Coffs Harbour* as an example, there are totally 12 categories of environmental planning maps, includes land use map, land zoning map, large-scale map, map of acid sulfate soils, scale map of area, map of heritage, map of building height, additional licensing map, map of land acquisition, urban area map, map of central business district, map of terrestrial biodiversity, water basin map, map of riparian land and waterways. This environmental planning does not involve maps of atmospheric environment, sound environment, solid waste, and electromagnetic radiation. From the point of planning system, the coverage of this planning is low, and it is close to *land use master planning* in our country.

5 The Technical Modules in Step 3: Preparing an Ecosystems Zoning and Protection Map

5.1 Module 3A: Map and assess ecosystems and landscapes

We are aware that no final solution for highly complex ecosystem service assessments has been found yet (Burkhart et al. 2014, p 3).

Currently, there exists little guidance on how to overcome the identified problems on ecosystem services (Wong et al. 2014)

The challenge for governments in protecting the environment – as the ultimate basis on which life depends – is to understand the relationships between the state of the environment and human impacts on the environment, that is, to understand causes and the effects.

As Albert et al. (2016) point out, one of the most widely used frameworks for managing human impacts on the environment is the Driving forces, Pressures, State, Impacts and Responses (DPSIR) model originally proposed by Smeets and Weterings in a report to the European Environmental Agency in 1999. DPSIR represents a framework for studying cause-effect relationships between socio-economic activities and the environment.

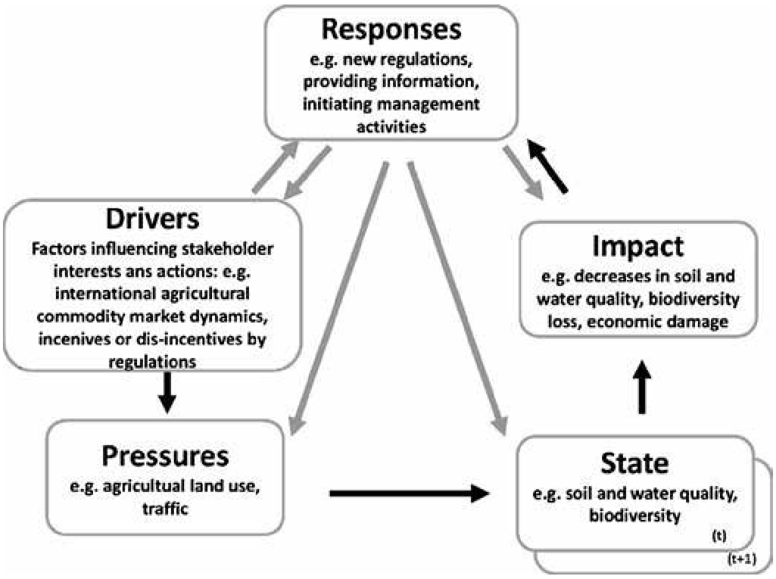


Figure 5-1-1 The DPSIR model

The grey arrows represent the potential paths of influence by planning.
Source: Albert et al. (2016), adapted from Smeets and Weterings (European Environment Agency 1999).

Albert et al. argue that '*Environmental indicators* are required *for all elements of this causal chain* in order to meet the information needs of policy makers' (2016, page 101, emphasis added).

In relation to environmental indicators, practice has varied significantly. Environmental indicators may measure natural capital, biodiversity, landscape integrity and many other variables. However, particularly since the UN's Millennium Ecosystem Assessment of 2001-2005 and the TEEB study (The Economics of Ecosystems and Biodiversity project commissioned by G8+5 in 2008 and led by banker Pavan Sukhdev) the focus has been on assessing *ecosystem services*.

Ecosystem services (and environmental services) are defined as the direct and indirect benefits that ecosystems provide to humans and the biosphere. To provide a structure for overlapping concepts, ecosystem services can be classified into provisioning services (for example, food, fuel, fibre, medicine), regulating services (for example, purifying air and water, preventing soil erosion, reducing the spread of disease), cultural services (for example, education, recreation, inspiration, physical and mental health) and supporting services that underpin the other three categories (for example, nutrient cycling, soil formation, primary production).

Three international classification systems are available to classify ecosystem services: MA, TEEB and CICES. In essence, they relate to a large extent to each other; all three include provisioning, regulating and cultural services.

MA. The Millennium Ecosystem Assessment (MA) was the first large scale ecosystem assessment and it provides a framework that has been adopted and further refined by TEEB and CICES. The MA organises ecosystem services into four well known groups:

1. provisioning services

2. regulating services

3. cultural services

4. supporting services

TEEB. TEEB proposes a typology of 22 ecosystem services divided in 4 main categories, mainly following the MA classification:

1. provisioning services

2. regulating services

3. habitat services

4. cultural and amenity services

An important difference TEEB adopted was the omission of supporting services, which are seen in TEEB as a subset of ecological processes. Instead, habitat services have been identified as a separate category to highlight the importance of ecosystems to provide habitat for migratory species (e.g. as nurseries) and gene-pool "protectors" (e.g. natural habitats allowing natural selection processes to maintain the vitality of the gene pool). The availability of these services is directly dependent on the status of the habitat (habitat requirements) providing the service. In case commercial species are involved, such as fish and shrimp species which spawn in estuarine and coastal nursery areas but of which adults are caught far away, this service has an economic (monetary) value in its own right.

CICES. The Common International Classification of Ecosystem Services offers a structure that links with the framework of the UN System of Environmental-Economic Accounts (SEEA 2003) which is currently being revised with a volume on ecosystem (capital) accounts to be published in the first half of 2013. CICES builds on the existing classifications but focuses on the ecosystem service dimension. In the CICES system services are either provided by living organisms (biota) or by a combination of living organisms and abiotic processes.

Region classification and boundary conditions adopted in millennium ecosystem assessment report are recommended. Concrete conditions are shown in the following table.

Table 5-1-1 Region Types in Millennium Ecosystem Assessment Report

Category	Main Concept	Boundary Division Condition
Sea	Ocean; fish fishing is typical driving force of the change;	Sea area with depth more than 50m.
Seashore	Boundary between sea and land; it is extended from sea to the middle of continental shelf, including all regions affected by marine factors at the mainland direction.	Region located between average sea depth of 50 meters and 50m above trend line, lowland within the scope extending from the seashore to mainland for 100km, including regional, estuaries, ocean aquaculture operation area of coral reefs, tide and low tide lines between the lines, and aquatic communities.
Inland Water	Permanent water outside the seashore and regions with ecological conditions and utilization conditions controlled by permanent, seasonal and intermittent flood;	Rivers, lakes, flood plains, reservoirs, and wetlands, including inland salt lake systems. Note: The Convention on Wetlands, the inland waters and the waterfront are designated as "wetlands.
Forest	Land wherein trees mainly grow, which is mainly used for producing timber, fuel and non-timber forest products.	Woody plant communities higher than 5 meters with canopy density less than 40%; Meanwhile, there are also some other recognized definitions and standards (for example, canopy density standard used by UN FAO is greater than 10%), including deforested land and plantation land, and excluding orchards and agroforestry systems based on production of food crops.
Dry Land	Land with crop production limited by water condition, which is mainly used for animal husbandry, including pasture and crop farming;	Dry land refers to land with annual precipitation less than two-thirds of annual potential evaporation according to definition given by 'Convention to Combat Desertification', including arid and dry sub-humid areas (ratio of precipitation and potential evapotranspiration is between 0.50 and 0.65), semi-arid, drought, extremely drought area (ratio of precipitation and potential evapotranspiration is less than 0.05), but not including polar regions. Dryland includes farmland, dwarf shrub woodland, shrub land, grassland, semi-desert and desert;
Island	Land isolated by waters in surrounding areas, wherein ratio between seashore and inland area is higher.	Please refer to definition in Alliance of Small Island States.
Mountain Land	Sharp land an land with high altitude	Definition of 'Mountain Guardian' is adopted as reference. It refers to adoption of the standard altitude. However, altitude, slope and local altitude change scope are adopted for distinguishing in areas with low altitude. It specially refers to the follows: area with altitude higher than 2500m; area with altitude between 1500m and 2500m, and slope greater than 2 degrees; area with altitude between 1000m and 1500 m, and slope greater than 5 degrees or local altitude (radius of 7 km) change greater than 300 m; area with altitude between 300m and 1000m, and local (radius 7 km) altitude change greater than 300 meters, isolated inland basin surrounded by mountains, and plateau with area less than 25km^2.
Farmland	It is mainly used for planting and cultivating plants, and used in crop, agroforestry or aquaculture production.	At least 30% of the landscape in the region is farmed every year, including orchards, agroforestry system, as well as complex system of agriculture and aquaculture industry.
City and Town	Construction environment with high population density	Known settled population is at least 5,000 people, which can be determined by observing stable and lasting lights at night; and the population can be presumed under the condition without the data.

Techniques for defining and assessing ecosystem services, and for assigning value to ecosystem services, have developed significantly over the past decade. These techniques remain the subject of intense research and debate, and testing through case studies and the development of plans and policies for places.

Burkhard et al. (2014) point out that major challenges in all ecosystem service assessment efforts are the high complexity of the topic itself and the need for universal and rather easy-to-apply approaches. The authors conclude that different classification systems and varying understandings of ecosystem service supply/benefit delivery chains among scientists have inhibited broad-scale practical applications so far.

In further developing the concepts of ecosystem services, distinctions have recently been made between ecosystem services that are 'offered' by ecosystems and those that are actually 'utilized' by humans (Albert et al., 2016), and in a similar distinction, between ecosystem service potentials, ecosystem service flows, and ecosystem service demands (Burkhart et al., 2014).

Tables 5-1-2 and 5-1-3, below, show the first and second of these matrices, namely ecosystem services potential and ecosystem services flow.

Table 5-1-2 An example of an evaluation of ecosystem services potential, in a hypothetical typical European landscape (in summer, before harvest period)

Source: Figure 4 in Burkhard, B. et al. ‘Ecosystem Service Potentials, Flows and Demands – Concepts for Spatial Localisation, Indication and Quantification’, *Landscape Online*, Volume 34, pages 1-32, 2014, page 15.

	Regulating services	Global climate regulation	Local climate regulation	Air quality regulation	Water flow regulation	Water purification	Nutrient regulation	Erosion regulation	Natural hazard regulation	Pollination	Pest and disease control	Regulation of waste
Continuous urban fabric		0	0	0	0	0	0	2	0	0	1	0
Discontinuous urban fabric		0	0	0	0	0	0	1	0	1	1	0
Industrial or commercial units		0	0	0	0	0	0	2	0	0	1	0
Road and rail networks		0	0	0	0	0	0	1	0	0	0	0
Port areas		0	0	0	0	0	0	3	3	0	1	0
Airports		0	0	0	0	0	0	1	0	0	1	0
Mineral extraction sites		0	0	0	0	0	0	0	0	0	0	0
Dump sites		0	0	0	0	0	0	0	0	0	0	2
Construction sites		0	0	0	0	0	0	0	0	0	0	0
Green urban areas		2	2	2	2	2	2	2	1	2	2	2
Sport and leisure facilities		1	1	1	1	1	1	1	0	0	1	1
Non-irrigated arable land		1	2	1	2	0	1	0	1	1	2	2
Permanently irrigated land		1	3	1	1	0	1	0	1	1	2	2
Ricefields		0	2	1	1	0	1	0	0	1	1	2
Vineyards		1	1	1	1	0	1	1	0	1	1	1
Fruit trees and berries		2	2	2	2	1	2	2	2	5	3	2
Olive groves		1	1	1	1	1	1	1	0	1	2	2
Pastures		2	1	0	1	0	1	1	1	0	2	4
Annual and permanent crops		1	2	1	1	0	1	2	1	1	2	2
Complex cultivation patterns		1	2	1	1	0	1	1	1	2	3	2
Agriculture & natural vegetation		2	3	2	2	2	2	2	1	2	3	2
Agro-forestry areas		2	2	2	2	2	2	3	1	3	3	3
Broad-leaved forest		5	5	5	3	5	5	5	4	4	4	4
Coniferous forest		5	5	5	3	5	5	5	4	4	4	4
Mixed forest		5	5	5	3	5	5	5	4	4	5	5
Natural grassland		5	2	0	1	3	4	5	1	1	1	2
Moors and heathland		3	4	0	2	3	3	2	2	2	2	3
Sclerophyllous vegetation		2	2	1	1	1	2	1	1	2	2	3
Transitional woodland shrub		2	2	1	1	1	2	1	1	2	2	3
Beaches, dunes and sand plains		0	0	0	1	1	1	0	5	0	1	1
Bare rock		0	0	0	0	1	0	2	1	0	0	0
Sparsely vegetated areas		0	1	0	1	1	1	1	1	0	1	1
Burnt areas		0	1	0	0	0	0	0	0	0	0	1
Glaciers and perpetual snow		3	4	0	5	0	0	0	0	0	1	1
Inland marshes		2	2	0	3	2	4	1	4	1	2	3
Peatbogs		5	4	0	4	4	4	2	3	2	3	4
Salt marshes		1	1	0	1	1	2	1	4	1	2	2
Salines		0	3	0	0	0	0	0	0	0	1	1
Intertidal flats		1	1	0	1	1	1	1	5	0	2	3
Water courses		0	1	0	3	3	3	0	3	0	3	5
Water bodies		1	2	0	5	2	3	0	3	0	3	5
Coastal lagoons		1	1	0	4	2	3	0	4	0	3	5
Estuaries		1	0	0	3	3	3	0	3	0	3	5
Sea and ocean		3	3	0	1	2	3	0	0	0	3	5

	Provisioning services	Crops	Biomass for energy	Fodder	Livestock (domestic)	Fibre	Timber	Wood Fuel	Fish, seafood & edible algae	Aquaculture	Wild foods & resources	Biochemicals & medicine	Freshwater	Mineral resources*	Abiotic energy sources*
Continuous urban fabric		0	0	0	0	0	0	0	0	0	0	0	0	0	1
Discontinuous urban fabric		1	0	0	0	0	0	0	0	0	0	0	0	0	1
Industrial or commercial units		0	0	0	0	0	0	0	0	0	0	0	0	0	1
Road and rail networks		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Port areas		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Airports		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mineral extraction sites		0	0	0	0	0	0	0	0	0	0	0	0	5	3
Dump sites		0	1	0	0	0	0	0	0	0	0	0	0	0	0
Construction sites		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Green urban areas		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sport and leisure facilities		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-irrigated arable land		5	5	5	0	5	0	0	0	0	1	3	0	0	2
Permanently irrigated land		5	1	2	0	4	0	0	0	0	1	3	0	0	1
Ricefields		5	1	2	0	0	0	0	0	0	0	0	0	0	0
Vineyards		4	1	0	0	0	0	1	0	0	0	0	0	0	0
Fruit trees and berries		4	1	0	0	0	2	2	0	0	0	2	0	0	0
Olive groves		4	1	0	0	0	2	2	0	0	0	2	0	0	0
Pastures		0	1	5	5	0	0	0	0	0	2	0	0	0	5
Annual and permanent crops		4	2	4	1	5	0	0	0	0	1	1	0	0	2
Complex cultivation patterns		4	2	2	1	4	0	1	0	0	1	2	0	0	1
Agriculture & natural vegetation		3	3	2	2	4	1	1	0	0	2	1	0	0	1
Agro-forestry areas		2	3	2	3	2	3	3	0	0	2	1	0	0	0
Broad-leaved forest		0	1	1	0	1	5	5	0	0	5	3	0	0	0
Coniferous forest		0	1	1	0	1	5	5	0	0	5	3	0	0	0
Mixed forest		0	1	1	0	2	5	5	0	0	5	3	0	0	0
Natural grassland		0	1	2	3	0	0	0	0	0	5	1	0	0	2
Moors and heathland		0	1	1	1	0	0	2	0	0	2	1	0	0	0
Sclerophyllous vegetation		0	1	1	1	1	2	2	0	0	1	3	0	0	1
Transitional woodland shrub		0	2	1	1	1	1	2	0	0	1	1	0	0	1
Beaches, dunes and sand plains		0	0	0	0	0	0	0	0	0	0	1	0	1	0
Bare rock		0	0	0	0	0	0	0	0	0	0	0	0	1	0
Sparsely vegetated areas		0	0	0	1	0	0	0	0	0	1	0	0	0	2
Burnt areas		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glaciers and perpetual snow		0	0	0	0	0	0	0	0	0	0	0	5	0	0
Inland marshes		0	0	4	2	0	0	0	0	0	1	0	0	0	0
Peatbogs		0	2	0	0	0	0	0	0	0	1	2	1	0	0
Salt marshes		0	0	2	2	0	0	0	0	0	1	0	0	0	0
Salines		0	0	0	0	0	0	0	0	0	0	2	0	2	0
Intertidal flats		0	1	0	0	0	0	0	0	0	1	0	0	0	0
Water courses		0	2	0	0	0	0	0	3	0	4	0	5	0	3
Water bodies		0	1	0	0	0	0	0	4	5	4	0	5	0	1
Coastal lagoons		0	1	0	0	0	0	0	4	5	4	1	0	0	0
Estuaries		0	2	0	0	0	0	0	4	5	4	1	0	0	1
Sea and ocean		0	4	3	0	0	0	0	5	5	4	3	0	1	3

	Cultural services	Recreation & tourism	Landscape aesthetics & inspiration	Knowledge systems	Religious & spiritual experience	Cultural heritage & cultural diversity	Natural heritage & natural diversity
Continuous urban fabric		3	3	2	2	1	0
Discontinuous urban fabric		3	2	2	2	2	0
Industrial or commercial units		0	0	0	0	2	0
Road and rail networks		0	0	0	0	1	0
Port areas		1	2	0	0	1	0
Airports		0	0	0	0	0	0
Mineral extraction sites		0	0	2	0	1	0
Dump sites		0	0	0	0	0	0
Construction sites		0	0	0	0	2	0
Green urban areas		3	3	1	0	2	1
Sport and leisure facilities		5	1	0	0	1	0
Non-irrigated arable land		1	1	2	0	3	0
Permanently irrigated land		1	1	2	0	3	0
Ricefields		1	1	2	0	3	0
Vineyards		3	2	3	0	5	0
Fruit trees and berries		3	2	2	0	4	1
Olive groves		2	2	2	0	4	0
Pastures		2	2	2	0	3	1
Annual and permanent crops		1	1	2	0	3	0
Complex cultivation patterns		2	2	2	0	3	0
Agriculture & natural vegetation		2	2	3	1	3	3
Agro-forestry areas		2	2	2	0	3	2
Broad-leaved forest		5	5	5	3	4	5
Coniferous forest		5	5	5	3	4	4
Mixed forest		5	5	5	3	4	5
Natural grassland		3	4	5	1	3	3
Moors and heathland		4	4	5	1	2	4
Sclerophyllous vegetation		2	3	4	1	2	4
Transitional woodland shrub		2	3	4	1	2	2
Beaches, dunes and sand plains		5	4	4	1	3	2
Bare rock		2	3	3	2	2	1
Sparsely vegetated areas		1	1	3	0	2	1
Burnt areas		0	0	2	0	0	0
Glaciers and perpetual snow		5	5	4	0	0	1
Inland marshes		1	2	3	0	2	2
Peatbogs		3	2	3	0	2	4
Salt marshes		3	2	3	0	2	2
Salines		2	2	3	0	4	0
Intertidal flats		4	2	3	0	2	2
Water courses		4	4	4	2	3	3
Water bodies		5	4	4	2	3	3
Coastal lagoons		3	4	4	0	2	3
Estuaries		3	4	4	0	2	3
Sea and ocean		4	5	5	2	3	3

*abiotic outputs from natural systems (after CICES)

Figure 4: Exemplary ecosystem service potential matrix. The exemplary evaluation refers to a hypothetical European „normal“ landscape in summer (before the harvest period). Scale from 0/rosy = no relevant potential; 1/grey green = low relevant potential; 2/light green = relevant potential; 3/yellow green = medium relevant potential; 4/blue green = high relevant potential; and 5/dark green = very high (maximum) relevant potential (after Burkhard et al. 2009 and 2012).

Table 5-1-3 An example of an evaluation of *ecosystem services flow*, in a hypothetical typical European landscape (in summer, before harvest period)

Source: Figure 5 in Burkhard, B. et al. 'Ecosystem Service Potentials, Flows and Demands – Concepts for Spatial Localisation, Indication and Quantification', *Landscape Online*, Volume 34, pages 1-32, 2014, page 16.

4.2 Ecosystem service flow matrix

	Regulating services	Global climate regulation	Local climate regulation	Air quality regulation	Water flow regulation	Water purification	Nutrient regulation	Erosion regulation	Natural hazard regulation	Pollination	Pest and disease control	Regulation of waste	**Provisioning services**	Crops	Biomass for energy	Fodder	Livestock (domestic)	Fibre	Timber	Wood Fuel	Fish, seafood & edible algae	Aquaculture	Wild foods & resources	Biochemicals & medicine	Freshwater	Mineral resources*	Abiotic energy sources*	**Cultural services**	Recreation & tourism	Landscape aesthetics & inspiration	Knowledge systems	Religious & spiritual experience	Cultural heritage & cultural diversity	Natural heritage & natural diversity
Continuous urban fabric		0	0	0	0	0	0	2	0	1	1	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0		3	2	2	2	1	0
Discontinuous urban fabric		0	0	0	0	0	0	1	0	2	1	0		0	0	1	0	0	0	0	0	0	0	0	0	0	1		2	1	2	2	2	0
Industrial or commercial units		0	0	0	0	0	0	2	0	1	1	0		0	0	0	0	0	0	0	0	0	0	0	0	0	1		0	0	0	0	2	0
Road and rail networks		0	0	0	0	0	0	1	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	1	0
Port areas		0	0	0	0	0	0	3	3	0	1	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0		1	2	0	0	1	0
Airports		0	0	0	0	0	0	1	0	0	1	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0
Mineral extraction sites		0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	3	1		0	0	1	0	0	0
Dump sites		0	0	0	0	0	0	0	0	0	0	2		0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0
Construction sites		0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	1	0
Green urban areas		2	2	2	2	2	2	2	1	2	2	2		0	0	1	0	0	0	0	0	0	0	0	0	0	0		3	3	1	0	2	1
Sport and leisure facilities		1	1	1	1	1	1	1	0	0	1	1		0	0	0	0	0	0	0	0	0	0	0	0	0	0		4	1	0	0	1	0
Non-irrigated arable land		1	2	1	2	0	3	0	1	3	2	2		0	0	0	0	0	0	0	0	0	0	0	0	0	0		1	1	1	0	1	0
Permanently irrigated land		1	3	1	3	0	3	0	1	3	2	2		0	0	0	0	0	0	0	0	0	0	0	0	0	0		1	1	1	0	1	0
Ricefields		0	2	1	4	0	3	0	0	1	1	2		0	0	0	0	0	0	0	0	0	0	0	0	0	0		1	1	1	0	2	0
Vineyards		1	1	1	1	0	1	1	0	2	1	1		0	0	0	0	0	0	0	0	0	0	0	0	0	0		2	1	2	0	4	0
Fruit trees and berries		2	2	2	2	1	2	2	2	3	3	2		0	0	0	0	0	0	0	0	0	0	0	0	0	0		2	1	1	0	3	1
Olive groves		1	1	1	1	1	1	1	0	2	2	2		0	0	0	0	0	0	0	0	0	0	0	0	0	0		2	2	2	0	3	0
Pastures		1	1	0	1	0	1	1	1	1	2	4		0	0	4	2	0	0	0	0	0	0	0	0	0	0		2	2	2	0	2	1
Annual and permanent crops		1	2	1	2	0	2	2	1	2	2	2		0	0	0	0	0	0	0	0	0	0	0	0	0	0		1	1	1	0	2	0
Complex cultivation patterns		1	2	1	2	0	2	1	1	3	3	2		0	0	1	0	0	0	0	0	0	0	1	0	0	0		2	2	1	0	2	0
Agriculture & natural vegetation		1	3	2	2	1	2	2	1	2	3	2		0	0	1	0	1	0	1	0	0	0	1	0	0	1		2	2	2	1	2	1
Agro-forestry areas		1	2	2	2	1	1	3	1	2	3	3		0	0	0	1	1	1	1	0	0	0	1	0	0	0		2	2	1	0	2	1
Broad-leaved forest		4	5	5	3	4	5	5	3	1	4	4		0	1	1	0	1	1	1	0	0	1	1	0	0	0		4	4	4	2	2	4
Coniferous forest		4	5	5	3	4	5	5	3	1	4	4		0	1	1	0	1	1	1	0	0	1	1	0	0	0		4	4	4	2	2	3
Mixed forest		4	5	5	3	4	5	5	3	1	5	5		0	1	1	0	1	1	1	0	0	1	1	0	0	0		4	4	4	2	2	4
Natural grassland		2	2	0	1	3	4	5	1	2	1	2		0	0	2	1	0	0	0	0	0	1	1	0	0	0		3	4	4	1	2	2
Moors and heathland		2	4	0	2	3	3	2	2	2	2	3		0	1	1	0	0	0	1	0	0	1	1	0	0	0		3	4	4	1	1	3
Sclerophyllous vegetation		1	2	1	1	1	2	1	1	1	2	3		0	0	1	0	0	1	1	0	0	1	0	0	0	0		2	3	4	1	1	3
Transitional woodland shrub		1	2	1	1	1	2	1	1	1	2	3		0	1	1	0	1	1	1	0	0	1	1	0	0	0		2	3	4	1	1	1
Beaches, dunes and sand plains		0	0	0	1	1	1	0	5	0	1	1		0	0	0	0	0	0	0	0	0	0	1	0	0	0		5	4	4	1	1	1
Bare rock		0	0	0	0	1	0	2	1	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0		2	3	3	1	1	1
Sparsely vegetated areas		0	1	0	1	1	1	1	1	0	1	1		0	0	0	1	0	0	0	0	0	0	0	0	0	0		1	1	2	0	1	1
Burnt areas		0	1	0	0	0	0	0	0	0	0	1		0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	2	0	0	0
Glaciers and perpetual snow		3	4	0	3	0	0	0	0	0	1	1		0	0	0	0	0	0	0	0	0	0	0	1	0	0		2	4	3	0	0	1
Inland marshes		2	2	0	2	2	4	1	4	1	2	3		0	0	2	1	0	0	0	0	0	0	0	0	0	0		1	2	3	0	1	1
Peatbogs		4	4	0	3	4	4	2	3	2	3	4		0	2	0	0	0	0	0	0	0	0	1	0	0	0		3	2	3	0	1	3
Salt marshes		0	1	0	1	1	2	1	4	1	2	2		0	0	2	1	0	0	0	0	0	0	0	0	0	0		3	2	3	0	1	1
Salines		0	2	0	0	0	0	0	0	0	1	1		0	0	0	0	0	0	0	0	0	0	2	0	2	0		2	2	3	0	3	0
Intertidal flats		1	1	0	1	1	1	1	5	0	2	3		0	0	0	0	0	0	0	0	0	0	0	0	0	0		4	2	3	0	1	1
Water courses		0	1	0	3	3	3	0	3	0	3	5		0	0	0	0	0	0	0	2	0	2	0	2	0	2		4	4	3	1	2	2
Water bodies		1	2	0	3	2	3	0	3	0	3	5		0	0	0	0	0	0	0	2	2	3	0	2	0	1		5	4	3	1	2	2
Coastal lagoons		1	1	0	2	1	3	0	4	0	3	5		0	0	0	0	0	0	0	2	2	2	0	0	0	0		3	4	3	0	1	2
Estuaries		1	0	0	2	3	3	0	3	0	3	5		0	0	0	0	0	0	0	2	2	2	0	0	0	0		3	4	3	0	1	2
Sea and ocean		2	3	0	1	1	3	0	0	0	3	5		0	1	1	0	0	0	0	3	2	3	2	0	1	1		4	5	3	1	2	2

*abiotic outputs from natural systems (after CICES)

Figure 5: Exemplary ecosystem service flow matrix. The exemplary evaluation refers to a hypothetical European „normal" landscape in summer (before the harvest period). Scale from 0/rosy = no relevant flow; 1/grey green = low relevant flow; 2/light green = relevant flow; 3/yellow green = medium relevant flow; 4/blue green = high relevant flow; and 5/dark green = very high (maximum) relevant flow (after Burkhard et al. 2009 and 2012).

The **objectives** of ecological service function promotion in urban and rural environmental master planning are shown in the table below.

Table 5-1-4 Objectives of ecological service function promotion in urban and rural environmental master planning

Positing	Put forward exploitation and protection planning theoretical framework of ecological service function orientation and establish the general thinking of ecological priority, partition boot and system integration
Pattern	Make urban ecology suitability assessment on the basis of urban ecological space pattern, mainly reflecting in two aspects: ● The evaluation purpose is to divide ecological function areas. Construction lands with homogeneous soil and being vacant now are used for meeting the demands of urban construction and development; and they have no space restriction to urban construction and development. In terms of their analysis, main focuses are natural elements, ecological environment and hydrological conditions; ● Evaluation should be organically combined with functional orientation and industry selection of regional ecological services, well handling one to one corresponding relation between ecological elements and human factors.
Promotion	Optimize urban economic and social functions and promote ecological service value based on urban ecology suitability analysis. Two aspects are concluded: ● Properly arrange all urban economic activities, satisfy function orientation of regional economy and effectively utilize ecological resources; ● Reasonably confirm the scale of ecological service functional zones, take social and economic development demands into consideration and take ecological conservation needs into account.
Post-assessment	Based upon post-assessment of ecosystem service function promotion effect, make multi-objective decisions by emphasizing both ecological and economic benefits.

The 10-Step approach

Christina P Wong and colleagues (2015) developed a 10-step approach to unify the concepts, methods and data from disparate disciplines. In Figure 5-1-2 the approach is presented in a stepwise form to clearly illustrate the technical integration of ideas. Currently, there exists little guidance on how to overcome the identified problems on ecosystem services. The intent is to offer an approach to guide choices on resource allocations for data collection and model selection, which vary depending on the study objectives and decision context (see Table 5-1-2). The guidance is strategic for public policy because analysts need to be: (1) realistic when setting priorities, (2) attentive to timelines to acquire relevant data, given resources and (3) responsive to the needs of decision-makers. The 10-step approach is about building craft not adherence to steps. Its effectiveness will depend on our ability to practice holistic and adaptive thinking (Lee, 1993) centred on how ecosystems support human welfare. Below, the steps in each phase are summarised.

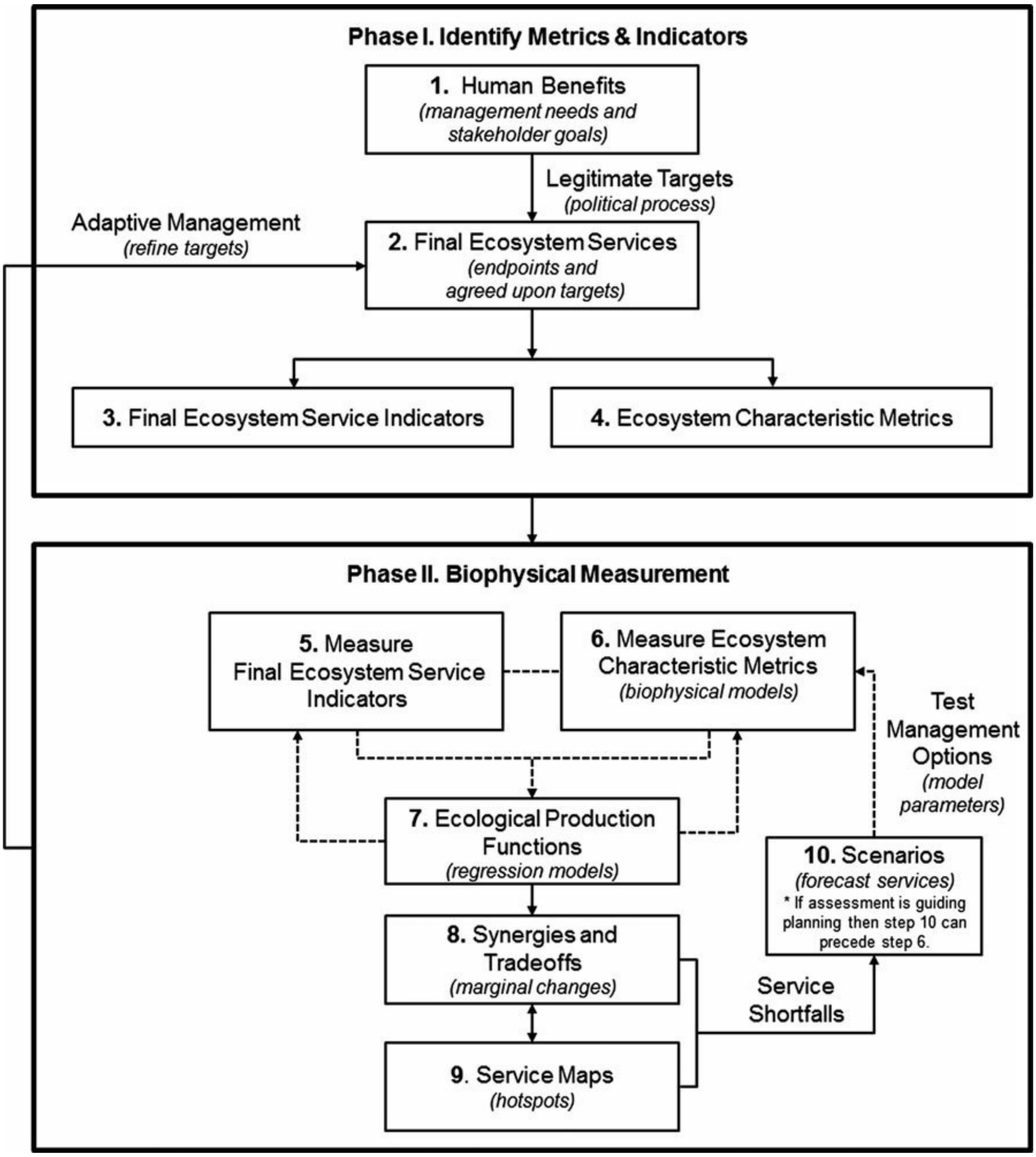


Figure 5-1-2 The 10-step approach

Source: Wong et al. (2015). Phase I is identifying final services, final service indicators and ecosystem characteristics metrics. Once these variables are selected then scientists can proceed to phase II to measure ecosystem services. Steps 5–7 are repeated until satisfactory ecological production functions are created. Steps 8 and 9 provide information on trade-offs and spatial patterns to understand service shortfalls, which inform scenarios in step 10 that feed model alterations in step 6. The dashed lines are the main modelling steps in phase II.

Phase I: Identify metrics and indicators (steps 1–4)

Human benefits represented as final services should guide the measurement process. The final service criteria are used to identify legitimate final services using endpoints and/or agreed upon stakeholder targets. The analyst must clearly indicate who selected the final services and the spatial–temporal extent of the assessment. Final services most applicable to public policy, clearly describe their connections to human well-being as management metrics in the given governance context. The biophysical units of final services guide scientists on selecting final service indicators and ecosystem characteristic metrics. The ecosystem characteristic metrics should represent key ecosystem components and management options supporting the final services. The challenge is seeing the connections between social and ecological variables to link final services, final service indicators and ecosystem characteristic metrics such as water quality, total nitrogen and nutrient retention as shown in Figure 5-1-3 (Wong et al. 2014).

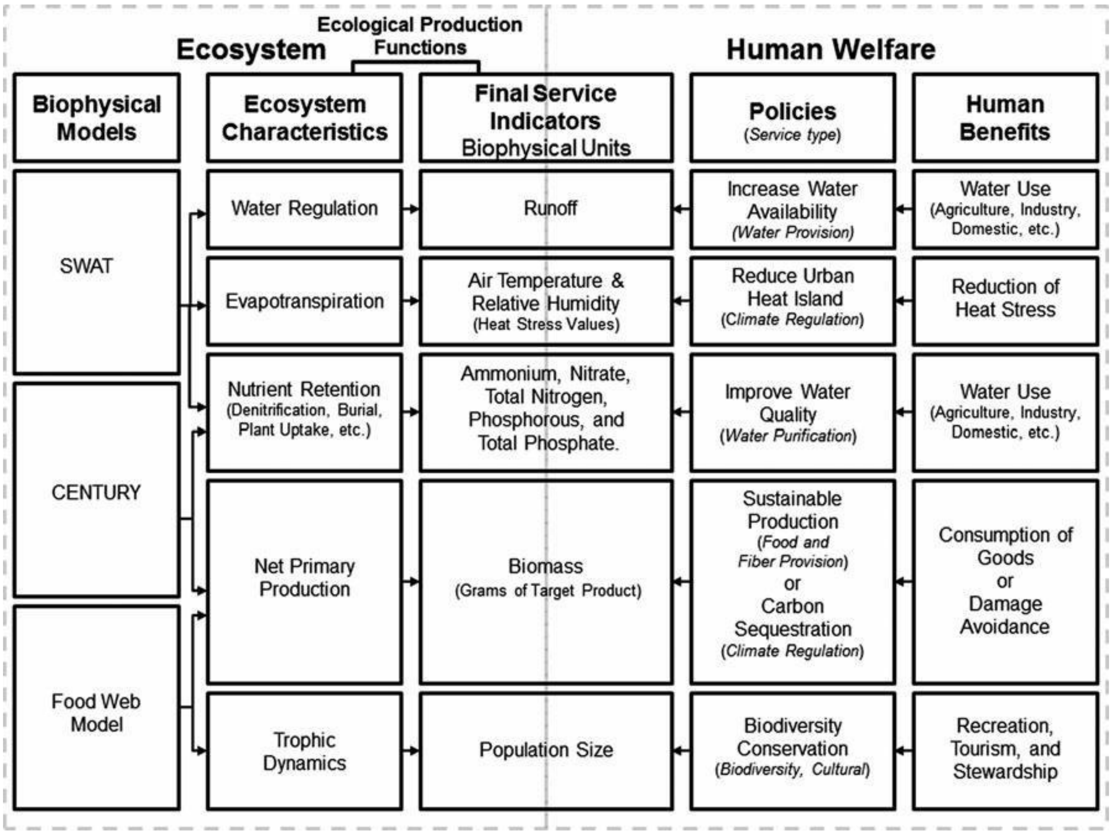


Figure 5-1-3 Examples of how to use final service indicators to link biophysical models, ecosystem characteristics, policy targets and human benefits

Source: Wong et al. (2015).

Assessment of ecosystem services

Key assessment model tools of ecosystem services include the InVEST model, the ARIES model and the SolVES model. Concrete model data needs are shown as follows.

Table 5-1-5 Data needs of InVEST, ARIES and SolVES models

Model	Sub-module	Data needs
InVEST	Carbon storage and sequestration	Land use/land cover (LULC) map, carbon pools, value of a sequestered ton of carbon etc.
	Bio-diversity	Land use/land cover (LULC) map, habitat threat factor score, habitat types and sensitivity of habitat types to each threat, accessibility to sources of degradation etc.
	Sediment retention	Land use/land cover (LULC) map, digital elevation model (DEM) data, rainfall erosivity index, soil erodibility, biophysical table etc.
	Managed timber production	Timber parcel map, timber production table, market discount rate etc.
	Crop pollination	Land use/land cover (LULC) map, table of pollinator species or guilds , table of land cover attributes etc.
	Reservoir hydropower production	Land use/land cover (LULC) map, annual precipitation, average annual potential evapotranspiration, soil depth, plant available water content (PAWC) fraction, biophysical table etc.

	Water purification	Land use/land cover (LULC) map, digital elevation model (DEM) data, average annual precipitation, average annual potential evapotranspiration, soil depth, biophysical table, water purification valuation table etc.
ARIES	Carbon storage and sequestration	Carbon sequestration layer, land cover map, percent tree canopy cover, vegetation type, fire frequency, soil carbon storage, vegetation carbon storage, slope map, soil PH, soil C:N ratio, GHG emissions, population density etc.
	Aesthetic view and proximity	Forest, farmland, fire threat, grassland, park, water quality, highways, housing values, urban proximity etc.
	Flood regulation	Annual precipitation, average annual actual evapotranspiration, average annual runoff, vegetation type, tree canopy cover, slope, impervious surface cover, highways, farmland, railways, floodplain extents etc.
	Sediment regulation	Average annual precipitation, average annual runoff, average annual soil loss, slope, soil texture, tree canopy cover, vegetation type, floodplain, stream gradient, farmland, reservoirs, floodplain etc.
	Freshwater supply	Precipitation, snowmelt, soil infiltration, actual evapotranspiration, annual maximum temperature, impervious surface cover, tree canopy cover, runoff, slope, vegetation type, well locations etc.
	Recreation	Amphibian, bird, mammal, reptile species richness, digital elevation model (DEM) data, hydrography, lakes and ponds, public lands, developed land, energy infrastructure, transportation infrastructure, scenic viewpoints, population density etc.
SolVES	Aesthetics	Environmental data, survey data, study area boundary and other spatial data like study area boundary
	Biodiversity	
	Cultural recreation	

Unit Price Assessment of Ecosystem Services

Ecosystem market price assessment is concretely related to the following methods: dose-response technique, changes in productivity approach, etc., specific methods and processes can be analyzed according to general financial cost, which will not be described here.

Ecosystem non-market value assessment includes the stated preference method (SP) and revealed preference method (RP). The two major categories also contain a variety of different methods, including stated preference methods such as contingent valuation method (CVM), Choice Experiment (CE), revealed preference methods such as travel cost method (TC), Hedonic Pricing Model (HP), replacement cost method (RC), Avoided Cost (AC), etc. (Gómez-Baggethun and Barton, 2013).

Concrete methods of assessment recommendation include: Hedonic pricing model, travel cost method, avoided cost and condition value assessment method.

Price Monetization of Ecosystem Services

Estimation of ecological service values are generally targeted for urban forest/green ecosystem aiming at overall planning of urban and rural environments. Values of various functions including soil conservation, conservation water source, flood regulation and accumulation, carbon fixation and oxygen releasing, climate regulation, clean environment, noise reduction, etc. are estimated.

Therefore, total value of ecosystem impact in the planned area is shown as follows:

$$\boldsymbol{R = E_{e1} + E_{e2} + E_{w} + E_{c} + E_{o} + E_{cr} + E_{p} + V_{1} + V_{2}}$$

In the Formulas, *R* refers to total value of ecosystem services, soil conservation function value ($\boldsymbol{E_{e1} + E_{e2}}$), conservation water source-flood regulation and storage function value ($\boldsymbol{E_{w}}$), carbon fixation and oxygen releasing value ($E_c + E_o$), local climate function regulation value (E_{cr}), environment purification function value (E_p), bactericidal function value (V_1) and noise reduction value (V_2) are shown on the right of equation in turn.

Table 5-1-6 Classification and Sorting of Ecosystem Services and Detailed Assessment Methods

Ecology function	Assessment index	Estimation Method	Parameter Meaning	Parameter Setting
Soil Conservation	Reducing loss of soil fertility, and reducing total land erosion;	Loss of soil fertility: $E_{e1} = \sum \delta * A * C_i * P_i^i$ Land erosion: $E_{e2} = \delta * A * \frac{B}{H}$ $\delta = M/\rho$	*A*: Woodland/green land coverage area: m^2 C_i : Nitrogen, phosphorus and potassium contents in soil: % P_i : Average price of nitrogen, phosphate and potash on the market: yuan/t *M*: Soil erosion modulus: $t/(km^2 * a)$ ρ : Average density of forest soil: t/m^2 *H*: Average thickness of forest soil: m B: Forestry average earnings: *yuan/(hm2*a)*	A: It can be obtained by querying the planning area survey data. C_i : It can be obtained by querying soil nutrient status survey data. P_i : It can be obtained by market survey. *M*: It can be obtained by querying survey data of China Water Network in associated watersheds and related areas. ρ : The value is $1.1t/m^2$ according to previous studies. *H*: It is calculated according to soil conservation amount and soil surface layer average thickness 0.6m. *B*: B: it is average earnings for forestry, and average earnings of forestry production in China is 28217 yuan/*(hm2*a)* according to data by National Bureau of Statistics.
Conservation Water Source	Water accumulation and water quality purification	$E_w = \theta * R * A * (C + K)$	*R*: precipitation: mm/a θ : Interception coefficient *C*: Capacity investment of reservoir construction unit: yuan/t. *K*: Water purification cost: yuan/t.	θ : It is selected according to plantation type, 20% can be selected for urban forest/green land. *R*: It can be obtained through querying meteorological data of planned area. *C&K*: Values are respectively obtained according to 'Forest Ecosystem Service Assessment Specification' (2007) C=6.11 yuan/t and K=2.09 yuan/t.
Carbon fixation and oxygen release	CO2 fixation and oxygen release	Carbon fixation: $E_c = A * C_c * (1.63R_c * B + F_e)$ Oxygen release: $E_o = A * C_o * 1.19B$	C_c : Carbon fixation price: yuan/t. C_o : Oxygen release price:yuan/t. R_c : Carbon content in CO2, and the value is 27.27% *B*: Forest net productivity : $t/(hm^2*a)$ F_e : Unit area forest soil fixed carbon content: $t/(hm^2*a)$	***B+F**$_e$* It is measured through remote sensing data. C_c : The value can be obtained through carbon tax method. C_C=1200 yuan/t (Forest Ecosystem Services Assessment Specification, 2007) C_o : Industrial oxygen production price 1000 yuan/t is adopted. (Forest Ecosystem Services Assessment Specification, 2007)
Climate regulation	Weakening ' heat island' effect, and lowering power consumption	$E_1 = \frac{1}{\alpha} * A * h * C * d * p$	1/a: Cooling coefficient : kWh/ ($d*m^3*°C$ *h*: Forest cooling space height: *m* *C*: "Heat island" intensity difference: *d*: Annual duration of cooling by air conditioner :*d/a*	1/a: It is set as 0.02315 according to related study (Xiao Jianwu, 2011) *h*: It is generally set as 5. *C*: Site survey is required. *d*: It can be generally set as 365/4=90d in summer.

			p: Average electricity price: Yuan/*kwh*	*p*: Yearbook can be consulted.
Environment purification	Air pollutant absorption	$E_p = \sum A * K_i * F_i$	K_i : i-th pollutant control cost: yuan/t F_i : Quantity of ith pollutant absorbed by unit area forest: kg/(hm^2*a) *i*: Representing sulfur dioxide, nitrogen oxides, fluorides, etc.	F_i : It is determined by querying forestry data, which also can be obtained according to previous studies (Peng Jian, 2005). $F_{SO2} = 88.65 kg/(hm^2 * a)$, $F_{NOx} = 380 kg/(hm^2 * a)$ Sulfur dioxide governance fee is calculated according to 600 yuan/t in 'China Biodiversity Studies National Study Report', price for absorbing nitrogen oxide is calculated according to financing standard average value 1340 yuan/t in China Air Pollutant Emission Charging Standards'.
Sterilization and bacteriostasis	Sterilization and bacteriostasis ability	$V_1 = \alpha_1 * T * q * A * (\frac{1}{K} - 1)$	α_1 is proportion coefficient of sterilization value in forest total ecological value; T: it is forest stumpage price: yuan/m^3 q: it is forest unit stock volume: *m^3/hm^2* K: Proportion value of forest direct use value in forest total ecological value;	α_1 : The value is generally 15% through the investigation or expert appraisal. *T*: It is obtained through market research *q*: It can be obtained through querying forestry statistics data. *K*: It is generally calculated according to 10%.
Noise reduction	Noise reduction ability	$V_2 = \alpha_2 * T * q * A * (\frac{1}{K} - 1)$	The method is the same as above description, and only proportion coefficient α_2 is different.	α_2 : General value is 10%

Phase II. Biophysical measurement (steps 5–10)

From phase I, the selected final service indicators and ecosystem characteristic metrics are the output and input variables of the ecological production functions. Available data and field methods are selected to estimate final service indicators and ecosystem characteristic metrics. Depending on the study objectives and scale, scientists should consider biophysical models by identifying applicable process-based or empirically based models. Biophysical models may be unnecessary if scientists can collect all the required primary data for ecological production functions at the scale of interest. If obstacles prevent primary data collection or use of biophysical models then established proxies or secondary data are appropriate when available. Measurement and evaluation is an iterative process (steps 5–10), and every unique combination of ecosystem characteristic metrics and final service indicators results in new production functions. An uncertainty analysis should be conducted, and estimated errors and assumptions reported. Using ecological production functions to relate biophysical model results to final service indicators can help scientists and management interpret the potential causes driving final service outcomes. However, when the analyst interprets marginality, it is important to consider the ecosystem state because a small increase or decrease in structure or function could lead to large step changes depending on the system’s proximity to a threshold.

Marginal changes are used to calculate potential synergies and trade-offs among services and management options. The service results are spatially evaluated using marginal changes and land cover to locate spatial patterns and determine potential beneficiaries. Scientists can use the trade-off results, mapping results and management input to select possible changes to management options to address service shortfalls. The selected changes inform model parameter alterations to run scenarios, and the production functions are used to forecast final service indicators under the scenario conditions.

The primary source for the following discussion is Bradley, T. and Hammond, H. *Practical Methodology for Landscape Analysis and Zoning*, Silva Forest Foundation, September 1993.

A protected landscape network is a set of ecologically viable habitat areas in urban and rural regions distributed across the landscape, and connected by defined movement corridors. The first component of the landscape network has already been identified - the protected riparian network. The landscape network components which remain to be added are protected old growth green land areas, protected cross valley movement corridors, and ecologically sensitive areas.

The idea of a network of connected habitats as a means of maintaining ecotypes and species has been developed by a variety of ecologists. Unique habitat types, specifically old growth green land, become isolated islands if/when they are "preserved" conventionally in managed landscapes. These "islands" are likely analogous to real oceanic islands, which were created by rising sea levels after the last ice age. Such islands start with the full complement of continental species, but gradually loose species through local extinctions.

In order to maintain ecosystem functioning and biodiversity, and to mitigate the problems created by habitat fragmentation due to extraction, ecologists support the creation of a systematic protected network of connected ecosystems within a landscape. Old growth islands are a critical part of this network, particularly within the managed forest. The size of habitat islands can vary, but a log normal distribution pattern is thought to be appropriate (i.e. a low number of the largest islands, more medium sized islands, many small islands, and a few tiny islands). The very large islands are important, and should occur in valley bottoms which contain the greatest species diversity and biological resources, not in the relatively sterile alpine areas. Smaller islands could occur in upper slope areas, which are close to extensive alpine ecosystems.

A combination of air photo interpretation and green land cover map analysis are used to identify the components of a protected landscape network. Old growth green land areas show up prominently on air photos, and can generally be immediately identified. Green land cover maps provide species, age, height and stocking information which may be useful. Digital map information and a GIS can provide the opportunity to perform interesting and informative map analyses to rate old growth green land areas in terms of ecological viability. Detailed analysis and rating may not be required in green land landscapes which have been impacted by human use. Possible large reserve areas, old growth green land nodes and movement corridors are often uncommon in such landscapes. In such situations, possible options for protected areas are often very few. Air photo interpretation alone is often sufficient to identify a network of protected areas.

The following landscape characteristic indexes are used for analyzing landscape structure characteristics according landscape characteristics of the studied area, thereby studying relationship between landscape structure and human activities.

(i) Landscape Dominance Index

Dominance index is larger, the deviation is greater, namely proportion difference of various type composing the landscape is larger, or one or a few landscape types are dominant; small dominance shows low deviation, namely proportion of various landscape types composing the landscape is roughly equivalent.

$$P_i = \sum_{i=1}^{n} a_{ij} / A \times 100$$

In the formula, P_i: landscape type; i: landscape proportion (%); a_{ij}: patch ij area (m^2); A: total landscape area (m^2).

(ii) Patch Density

It can reflect fragmentation of the landscape and landscape spatial heterogeneity. PD is greater, the fragmentation is smaller, and the spatial heterogeneity is smaller.

$$PD = N / A \times 10000 \times 100$$

In the formula, *PD*: patch density (1/100hm^2); *N*: patch number in landscape; *A*: landscape area (m^2).

(iii) Edge Density

Edge density refers to unit area edge length in the landscape, which can reflect landscape fragmentation, and edge density directly affects edge effect and species composition.

$$ED = E / A \times 1000$$

In the formula, *ED*: edge density (m/hm^2); *E*: landscape edge length (m); *A*: landscape area (m^2).

(iv) Mean Patch Fractal Dimension

Fractal dimension is used for determining the ecological process that patch shape affects internal patch, such as animal migration and substance exchange. The following formula can be used for measuring complexity of patch shape. MPFD value is between 1 and 2, MPFD is closer to 1, patch shape is simpler; on the contrary, MPFD is closer to 2, patch shape is more complex.

$$MPFD = \left(\sum_{i=1}^{m} \sum_{j=1}^{n} \left(2\ln(0.25P_{ij} / \ln a_{ij} \right) \right) / N$$

In the formula, *MPFD*: mean patch fractal dimension; P_{ij}: perimeter of patch *ij* (m); a_{ij}: area of patch *ij* (m^2); *N*: patch quantity in the landscape; *m*: landscape type quantity; *n*: patch number of some landscape type.

(v) Landscape Diversity Index

Landscape Diversity Index is shown as follows:

$$H = -\sum_{i=1}^{m} (P_i \times \ln P_i)$$

In the formula, *H*: diversity index; P_i: the proportion of landscape *i* in the area; *m*: landscape type quantity.

(vi) Mean Proximity Index

The index is used for measuring landscape fragmentation. When MPI is 0, patches in the same type are not adjacent in the appointed search radius. MPI is larger, aggregation of patches in the same type is larger, and fragmentation is smaller.

$$MPI = \left(\sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{s=1}^{n} \frac{a_{ijs}}{h_{ijs}} \right) / N$$

In the formula, *MPI*: mean proximity index; a_{ijs}: area of similar patches *ijs* within appointed distance from patch *ij*; h_{ijs}: distance between similar patch *ijs* and patch *ij* within appointed distance from patch *ij*; *N*: patch quantity in landscape.

All of the analysis work thus far has been carried out on air photos. After the zone boundaries have been finalized on the air photos, they must be transferred to a planimetrically reliable base on which zone areas can be measured. Rugged topography causes distortion in air photos, which are taken at relatively low elevations. The side of a mountain facing towards the airplane appears larger than it really is on ground, while the mountainside facing partially away looks much smaller than it really is. This distortion makes accurate area measurement directly from air photographs impossible.

Several methods exist to transfer type lines from air photos to a maps. Consultants with digital image processing equipment can perform this task, but are expensive. Transferring the information "by eye" from the typed air photos to green land cover or topographic maps is possible, but difficult. We have found this method to be time consuming and inaccurate - the level of detail on the target map is often insufficient and long expanses of line must be visually estimated.

Our preferred method is to transfer the type lines by hand to a clear film overlay on an ortho photo or Landsat satellite image color print. The Landsat image is obtained from a satellite in space; the greater altitude of the satellite "photography" largely eliminates the scale distortion problem common to air photos. We have found that areas measured by hand, or lines digitized into a GIS, from a satellite print provide acceptably accurate maps.

The zone boundaries from the air photos can be transferred to the satellite image by using a simple "relation to visible landforms" method. Many terrain features which are visible on the air photos are also visible on a Landsat image. Exposed rock, alder slides, forest type boundaries, stream beds, brushy areas and cut blocks are readily visible on the satellite print. The zone boundaries on the air photos are transferred to the satellite image based on their distance from or congruence with biophysical features common to both images. For example, a zone boundary which extends around the top of an alder slide, through a green land area to a small rock opening, then to the bend in a creek draw on the air photo would be drawn through the same set of points on the Landsat overlay. Using air photos and a satellite image with similar scales makes this process much more efficient.

Each zone should be colour coded by zone type and assigned a unique polygon number as they are transferred to the or satellite image. The unique polygon number is required to identify the zone in the computer data entry, editing, and analysis process.

Final identification of zone boundaries occurs on the ground during planning and implementation of various human activities.

At the moment, major methods to research characteristics and evolution of landscape pattern contain spatial statistical analysis, transition matrix analysis, landscape index analysis method, landscape simulation based on cellular automaton, etc.

As the most basic analysis approach, spatial statistical analysis can work out acreage, proportion, increase and decrease conditions in different periods and other relevant values of various land types by using remote sensing classification results of land utilization and land cover change. Landscape index analysis method can commonly analyze and uncover basic pattern characteristics and evolution laws of land utilization and land cover change by using degree of fragmentation index, diversity index, evenness index, and so on. Cellular automata can better simulate landscape pattern and process and its method and theory are fit for evolution study of landscape pattern strongly dependent on spatial and temporal scale.

Core breakthrough of current landscape pattern reconstruction method is to refine ecological service functions and ecological environmental sensitivity of key ecological elements on the basis of ecological function zoning, to set up influential relation relevance between urban patter and ecosystem process and functions (as shown in table below), to determine its development intensity control and impact on urban economic activity layout and to provide the basis for specific spatial implementation of later economic functions, ecological structure maintenance and multiple development, utilization and protection of ecological resources.

Table 5-1-7 Urban Pattern's Influence on Ecosystem Process and Functions

Ecosystem Process and Functions	Urban Pattern's Influence on Ecosystem
Productive Process of Net Primary Productivity	● Urbanization usually occurs in regions with high quality soil. ● Annual net primary productivity of urban areas is lower than that before urbanization.
Biodiversity Plant	● Alien species increase. ● Local species decrease.
Birds	● Urbanization has changed bird populations in cities, leading an increase in exotic species and decrease in local species. ● Urbanization has altered survival conditions of birds, such as cave living habit, predation way, etc. ● Urban landscape pattern has affected spatial distribution of bird populations.
Amphibians, Fish and Other Invertebrates	● Biodiversity of amphibians, fish and other invertebrates has been decreased along with the increase of urban construction land use. ● Fish in rivers with well-maintained ecological environment of riparian zone is less influenced by urbanization. ● Biological integrity in deep-water zone of water bodies influenced by urbanization has declined; the above impact will weaken in rivers with well-maintained ecological environment of riparian zone.
Cyclic Process of Materials	● Energy consumption of urban ecosystem is 100 ~ 300 times larger than that of natural ecological system. ● Cyclic process of nutrient materials is complex: ➢ High concentration of phosphorus in urban drainage basin ➢ High degree of nitrogen release, erosion and mineralization in cities ➢ Low natural degradation ability ➢ High concentration of heavy metals and organic matter and high degree of soil acidification
Hydrologic Process	● surface runoff increase ● catchment ability improvement ● increase of flood frequency of occurrence ● increase of runoff pollution load ● soil erosion aggravation

Albert et al. (2016) present a case study which 'shows how planning can benefit from differentiating between offered ecosystem services, human inputs, and utilized ecosystem services. Key benefits of these amendments to existing approaches lie in providing a better basis for accounting and subsequent decision-making, as the current pressures are considered and the role of human intervention in actually providing usable ecosystem services is exemplified' (p 101). The objective of the paper is to 'integrate the definition, assessment, and valuation of ecosystem services indicators into landscape planning based on the DPSIR model' (p 101). The authors describe this as a DPSIR-based 'ES-in-Planning' framework.

This is important, the authors argue, since ecosystem service 'models and indicators [need] to relate to the existing planning and governance frameworks in order to be applied in landscape management… [thus] providing the means to evaluate anthropogenic pressures and impacts, and to identify locations where response measures are likely to be most beneficial' (p 100).

In their case study of an area of about 6200 ha in the region of Hanover, Germany, the authors consider the following four categories of ecosystem services: food production potential, climate mitigation with respect to carbon storage in soils, landscape aesthetics as the basis for many cultural ecosystem services, and biodiversity in terms of habitats. The ecosystem services were selected to include each of the key categories for provisioning services, regulation and maintenance services, cultural services, as well as for biodiversity (Albert et al 2016, p 103).

Given the high quality of the data available for the relatively small area studied, the authors are able to present detailed and comprehensive findings, confirming the potential of the 'ES-in-Planning' framework. Nevertheless, they recognise that, notwithstanding the imperative to protect the environment, it is unlikely that the concept of ecosystem services will be fully mainstreamed in planning instruments in the short term, considering the limits of time, funding and data. Countries may take different routes to protecting the environment through regulatory planning, possibly including the following options:

- retrofitting existing plans and programs with considerations of ecosystem services;
- incrementally integrating assessments of ecosystem services in existing planning procedures;
- an environment-led approach that embeds ecosystem services considerations at early stages of planning; and
- an ecosystem approach-based model that fundamentally alters planning procedures toward better considering ecosystem services and their values in decisions.

Finally, the authors also acknowledge that it is not yet clear if investing more resources in acquiring additional ecosystem services information will actually yield a better consideration of environmental aspects in planning (Albert et al 2016, p 112).

Burkhart et al (2014) consider a typical (though hypothetical) European landscape, enabling them to elaborate the ecosystem services into eleven regulating services, fourteen provisioning services, and six cultural services, as listed in Table 5-1-8.

Table 5-1-8 Ecosystem services applicable to a typical European landscape

(Burkhart et al. 2014)

Regulating services	Provisioning services	Cultural services
Global climate regulation	Crops	Recreation and tourism
Local climate regulation	Biomass for energy	Landscape aesthetics and inspiration
Air quality regulation	Fodder	Knowledge systems
Water flow regulation	Livestock (domestic)	Religious and spiritual experience
Water purification	Fibre	Cultural heritage and cultural diversity
Nutrient regulation	Timber	Natural heritage and natural diversity
Erosion regulation	Wood Fuel	
Natural hazard regulation	Fish, seafood and edible algae	
Pollination	Aquaculture	
Pest and disease control	Wild foods and resources	* Abiotic outputs from natural systems (after CICES); often not acknowledged as ecosystem services, but of high relevance for policy decisions and land use/resource management.
Regulation of waste	Biochemicals and medicine	
	Freshwater	
	Mineral resources*	
	Abiotic energy sources*	

The matrix the authors use in their analysis evaluates these possible ecosystem services for each of 44 land cover types or classes, as listed in Table 5-1-9.

Table 5-1-9 Land cover types applicable to a typical European landscape

(Burkhart et al. 2014)

Land cover		
Continuous urban fabric	Fruit trees and berries	Beaches, dunes and sand plains
Discontinuous urban fabric	Olive groves	Bare rock
Industrial or commercial units	Pastures	Sparsely vegetated areas
Road and rail networks	Annual and permanent crops	Burnt areas
Port areas	Complex cultivation patterns	Glaciers and perpetual snow
Airports	Agriculture & natural vegetation	Inland marshes
Mineral extraction sites	Agro-forestry areas	Peatbogs
Dump sites	Broad-leaved forest	Salt marshes
Construction sites	Coniferous forest	Salines
Green urban areas	Mixed forest	Intertidal flats
Sport and leisure facilities	Natural grassland	Water courses
Non-irrigated arable land	Moors and heathland	Water bodies
Permanently irrigated land	Sclerophyllous vegetation	Coastal lagoons
Ricefields	Transitional woodland shrub	Estuaries
Vineyards		Sea and ocean

From this understanding of the landscape, Burkhart et al. (2014), like Albert et al. (2016), recognise specific characteristics in ecosystem services. They distinguish between *potential* ecosystem services and the actual *flows* of ecosystem services. They identify ecosystem service *demand*. At the outset, they consider *ecosystem functions*, as indicated in Figure 5-1-4.

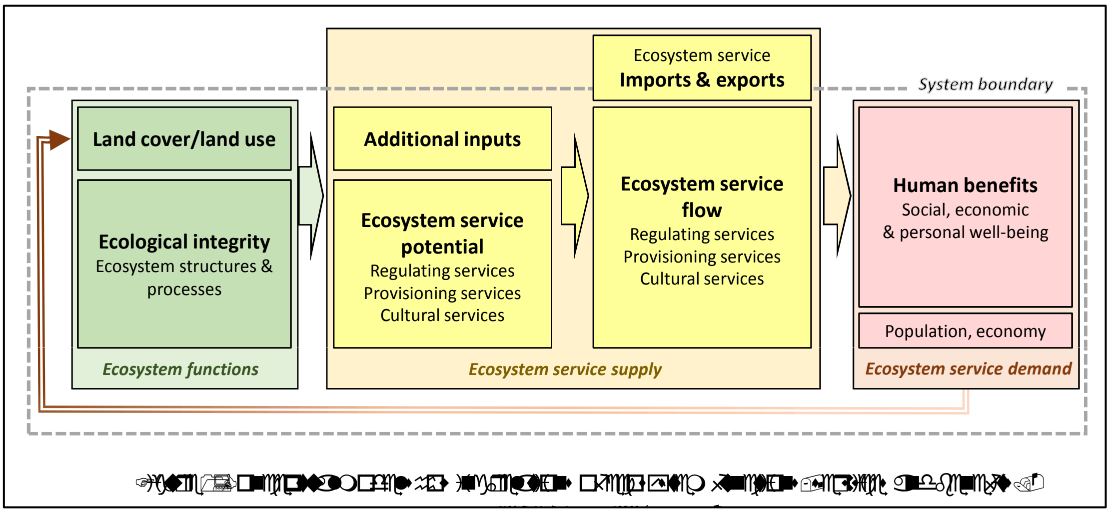


Figure 5-1-4 Conceptual model that relates to the DPSIR framework and integrates the concepts of ecosystem functions, ecosystem service supply (distinguishing between potential and flow) and ecosystem service demand.

Source: Burkhard, B. et al. 'Ecosystem Service Potentials, Flows and Demands – Concepts for Spatial Localisation, Indication and Quantification', *Landscape Online* Volume 34, pages 1-32, 2014, page 6.

The spatial application of these concepts calls for the identification and where feasible the *mapping* of both *service providing units* and *service benefiting areas*. The former includes the total collection of organisms, their abundance, phenology, distribution and trait attributes required to deliver certain ecosystem services as well as abiotic components (water bodies, soil units) hosting the service supplying ecosystems. The *service benefiting areas* are complementary to service providing units, but in contrast they do not relate primarily to ecosystems or geobiophysical units but to beneficiaries such as urban areas or rural settlements, likely to be defined as administrative and/or planning units (Burkhart et al 2016, pp 6-7).

In mapping the provision of *ecosystem* services, planners should identify service providing units or areas affected by related processes (floodplains, catchments). Hotspots (and coldspots as their opposite) of ecosystem service supply are special types of service providing units. They can be either small local point sources or larger sources within larger service providing units. Times of particularly high ecosystem service supply, for example due to seasonal variations, can be identified as hot moments. It is highly relevant for landscape management to identify spatial hotspots and temporal hot moments of ecosystem service supply and demand (Burkhart et al 2016, pp 6-7).

In undertaking this mapping, while the demand side may be administrative and/or planning units, the supply of ecosystem services should be identified as ecosystems or natural areas, rather than administrative units, which often mark artificial system boundaries (Burkhart et al 2014, p 6).

Conclusions

This Technical Guideline for Module 3A comes to the following conclusions.

1 It is essential that ecosystem services are placed strongly at the centre of the early stages of preparing a UREMP Plan.

- After developing an understanding of the essential environment characteristics of the potential UREMP Area and agreeing to the composition of any UREMP Partnership and the precise boundaries of the UREMP Area (Step 1)…
- and after establishing a mapping and data platform (Step 2)…
- the UREMP planners must broadly identify the ecosystems that provision and regulate the environmental benefits received by human society, and provide cultural benefits.

2 In the long run, it is essential that the UREMP planners:

- As a baseline, where data is available, document the characteristics of the UREMP Area (possibly including topography, soils, geology, hydrology, mesoclimate, habitat and biodiversity, flora and fauna, areas of land use, areas of land cover types, water quality, air quality, natural productivity for food and fibre, emission, fixation and storage of greenhouse gases, and cultural assets) in the process drawing on, and revising, the findings in Step 1.
- Document and map the driving forces affecting the environment (interests, motivations, market forces, regulations, traditional practices, etc).
- Document and map the pressures on the environment (development and other pressures, such as urban expansion, infrastructure, vegetation clearing, mining, traffic, sealing of the surface, and pollution load, as initially identified in Step 1).
- Where data is available, document and map the state of the environment – values, sensitivity, vulnerability – for critical ecosystem services, such as climate protection (sequestration and storage of greenhouse gases), soil fertility and productivity for agriculture and forestry, water provisioning (surface catchments and ground water), storm water retention, local climatic functions, renewable energy potential, cultural ecosystem services (aesthetic value, heritage, recreation).
- Where data is available, assess the impact of the identified pressures on the identified ecosystem services.
- In all cases, broadly identify the responses that are necessary to reduce impacts and reverse the loss of ecosystem services.

3 As shown clearly above, the theory, techniques and practice of valuing ecosystem services is on the cutting edge of science and practice. While improvements in concepts and methods are being made all the time, including notably by the environmental scientists of the PRC, there is no settled model or methodology for comprehensively valuing ecosystem services and managing change to protect those ecosystem services.

4 UREMP is a major (and globally significant) initiative to protect the environment, and must take advantage of environmental protection strategies that are simple, tested, and feasible. Assessing the value, sensitivity, and vulnerability of ecosystems that provide services to society are an essential element of the UREMP process.

5 Initially, these assessments may be constrained by unfamiliarity, and shortages of time, funding and data. Nevertheless, it is essential that this work begins, so that it can continue to improve and evolve with the institutionalisation of UREMP.

6 Step 4 takes these initial investigations much further. Green Land takes a number of forms – farm land, forests, mining areas, coasts, areas to be rehabilitated, hazardous areas – each with its own challenges in relation to sustainability and the protection of ecosystem services (whether or not the ecosystem services have been accurately identified and valued). Step 4 is concerned with environmental protection related to Green Land.

7 Likewise Step 5 is concerned with environmental protection related to water. The PRC has developed comprehensive standards and methods for managing water resources. Step 5 applies these practices to UREMP.

8 Step 6 applies the PRC's well established air monitoring and regulating systems to UREMP.

5.2 Module 3B: Indicative regional ecosystems protection zoning and mapping

An ecosystem is usually defined as a complex of living organisms with their (abiotic) environment and their mutual relations in urban and rural regions. Although this definition applies to all hierarchical levels (from a single water drop with its microorganisms to Earth's biomes), for the practical purposes of mapping and assessment, an ecosystem is here considered at the scale of habitat/biotope or landscape. A practical approach to the 'spatial delimitation of an ecosystem' is to build up a series of overlays of significant factors, mapping the location of discontinuities, such as in the distribution of organisms, the biophysical environment (soil types, drainage basins, depth in a water body), and spatial interactions (home ranges, migration patterns, fluxes of matter). A useful ecosystem boundary is the place where a number of these relative discontinuities coincide. Ecosystems within each category share a suite of biological, climatic, and social factors that tend to differ across categories. More specifically, there generally is greater similarity within than between each ecosystem type in:

- climatic conditions;
- geophysical conditions;
- dominant use by humans;
- surface cover (based on type of vegetative cover in terrestrial ecosystems or on fresh water, brackish water, or salt water in aquatic ecosystems);
- species composition;
- resource management systems and institutions.

Ecosystem mapping is the spatial delineation of ecosystems following an agreed ecosystem typology (ecosystem types), which strongly depends on mapping purpose and scale. Mapping in the broader sense may also include mapping of status (including functioning and health) as the result of monitoring and assessment of the ecosystem's quality but in many cases this is considered to be object of ecosystem assessments.

The urban and rural ecosystem as delineated from Land Cover classification and map are subdivided into construction land, cropland, grassland, woodland and forest, heathland and shrub, sparsely vegetated land, wetlands, river and lake, and marine ecosystems.

A significant source for the following discussion is Maes J et al. *Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020*. Publications office of the European Union, Luxembourg, 2013.

Research on mapping of ecosystem services is increasing. As a result of different methodological approaches, different sets of indicators are being used to assess individual services, resulting in different units in which ecosystem services are expressed. For example, different proxies are often used to study air quality regulation including fluxes in atmospheric gases between vegetation and the air, atmospheric cleaning capacity of vegetation or levels of pollutants in the air. These discrepancies evidently have implications for estimating monetary values.

Several approaches to mapping ecosystem services exist:

Deriving information on ecosystem services directly from land-use/cover or habitat maps. Such approaches may be appropriate at national scales, for areas where the dominant service relates directly to land use (e.g. crop and timber production) or where data availability or expertise is limited, and where the focus is on the assumed presence of ecosystem services rather than on quantification of the supply. This method is often coupled to value transfer. Ecosystem service values are transferred from existing valuation studies to other areas using land cover data for value transfer.

Primary data to map ecosystem services are used for provisioning services where statistics are available. Examples include timber, food, or water supply. Statistical data usually relate to certain administrative units. Socio-economic analysis linked to environmental assessments can be also obtained from the sources of information mentioned in the previous section.

Recent mapping techniques are based on biological data such as functional traits of plants or ecosystem structure and habitat data. Functional traits, such as vegetation height, leaf dry matter content, leaf nitrogen and phosphorus concentration, flowering onset, can be used to map several services.

Output: The first red line map

The output of Module 3B is the first of the series of indicative zoning maps showing red, yellow and green lines (zones). This map, and the others from Steps 4, 5, 6 and 7, are called 'indicative' because they each show these protection zones in relation to a single set of parameters. At this stage, the indicative protection zones show a ranking, and a set of policy measures, that need to be reconciled and negotiated before they can be integrated into the final UREMP protection zoning map that is the output from Step 8.

Within Module 3B, the same reconciliation and negotiation needs to take place to integrate the outputs of Module 3A. This is a task that needs to involve the whole UREMP team, since decisions are being made about values, ranking, priorities and regulations. It also should involve representative of neighbouring UREMP teams (if neighbouring teams exist) or alternatively representatives of neighbouring provinces and local governments, since natural systems exist (and need protection) on both sides of all UREMP boundaries.

When the layers of spatial information from Module 3A are combined to produce a new set of defined areas zoned red, yellow and green, the data underlying the ranking of each area needs to remain associated with that area. In other words, red, yellow and green protection zones are not uniform. They comprise many sub-areas based on competing values and competing policy responses, which must be capable of being explained and justified. Likewise, being zoned red, yellow or green does not carry with it a single set of opportunities and constraints. Any subarea of these zones may be subject to a set of regulations that are specific to that subarea, and that must be capable of being explained and justified.

The output of Module 3B is an indicative ecosystems protection zoning map and databases relating to ecosystems and landscape units in the UREMP Area. This becomes critical input to the preparation of the UREMP integrated environmental protection zoning map in Step 8.

5.3 Examples

5.3.1 Functional Orientation and Goals for Environment (Yichang)

On account of cities' status in nationwide, regional and watershed ecosystems in China, based on research analysis of regional ecosystems, including its structure function, species diversity, biotic migration channel, etc. and combining with large scale remote sensing images and space geographic data, analyze cities' status in large scale ecosystem pattern and its significant ecosystem service functions and determine the target of urban ecological environment functional orientation and maintenance.

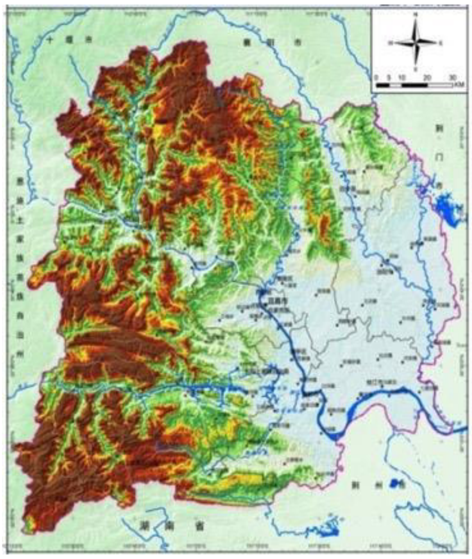


Figure 5-3-1 Ground Elevation Map of Yichang City

Figure 5-3-2 Distribution Diagram of State-level Key Ecological Function Areas

Taking Yichang as an example, make sure ecological environment functional orientation of Yichang through analysis of large scale ecosystem pattern as follows: (1) It is an important nodal region to maintain water ecology and water environmental functions of overall Yangtze River drainage basin. (2) As a transitional zone from Qinling and Dabashan Mountains to Jianghan Plain, it is a typical example of complex ecological environment with strong environmental sensitivity, meanwhile, it plays an important role in guaranteeing ecological environmental security of the Three Gorges Reservoir Region and western areas of Hubei Province. (3) It is a gene bank to preserve endangered species of China and a crucial area to protect species abundance, having vital function in safeguarding national species security.

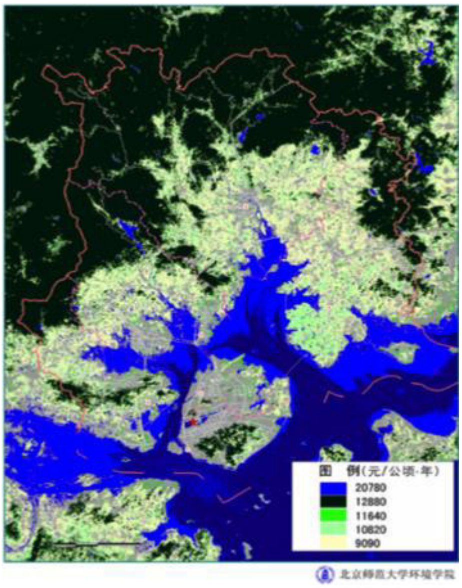
5.3.2 Ecological Service Value Assessment (Xiamen)

According to remote sensing data and related vegetation information, respectively calculate direct economic value (including forest product value and productive value of planting industry) and indirect economic value (encompassing various ecological service function value like water conservation, soil conservation and cultivation, carbon sequestration and oxygen production, air purification, and so on) of different ecosystem-types, identify space and type differences of ecosystem service functions, and clarify key protected areas.

Special Column 1:

Measurement and Calculation of Ecological Service Value of Xiamen

In reference to remote sensing data and vegetation information provided by electronic map, divide natural ecosystem of Xiamen city into 4 broad categories and evaluate its ecological service function value:



- Forest Ecosystem: according to planning requirements and forest distribution characteristics of Xiamen, forest ecosystem of this city can be divided into general woodlands and economic forests. In terms of general forests, timber forests, shrubberies, open forests, small area woodlands, scenic beauty forests, etc. are included. While economic forests are consist of orchards, tea plantations, etc.
- Grassland Ecosystem: including grasslands, nursery gardens, flower beds, cities, other types of green space, farms, forest farms, pastures, etc.;
- Farmland Ecosystem: containing irrigable lands, dry lands, economical crop lands, vegetable fields, etc.;
- Wetlands: composed of shallow water areas, tidal flats, estuarine waters, river systems, ponds, etc.

As for all ecosystem types above, respectively calculate its direct economic value (including forest product value and productive value of planting industry) and indirect economic value (encompassing various ecological service function value like water conservation, soil conservation and cultivation, carbon sequestration and oxygen production, air purification, and so on).

Ascertain evaluation index weights by adopting following methods: (1) weighted value of water conservation function: it is determined by difference value of water resource supply and demand in different evaluation unit, topographic slope and soil type. (2) weighted value of carbon sequestration and oxygen production functions as well as dust-retention ability: they are acquired by urban land proportion in total area and its distance from city: the greater proportion of urban land is, the bigger value of above two service functions will be; while the farther from city, the smaller value of ecological service function will be. (3) weighted value of air pollutant absorption function: it can be comprehensively obtained according to whether concentration of current air pollutants can meet corresponding national standards and spatial distance from core areas of the city. (4) weighted value of soil conservation and cultivation function: mainly give consideration to topography and soil types.

Calculation results (the left figure: spatial distribution map of ecological service function value of Xiamen) show an obvious spatial variation of natural ecosystem ecological service function of Xiamen, among which Maluan Bay, Xinglin Bay and water reservoir area have the highest ecological service function value. However, owe to serious pollution of Maluan Bay and other regions which have greater impact on urban ecological balance, it is particularly significant to strengthen wetland protection and planning in this area.

5.3.3 Division Means to Promote Ecological Function (Xiamen)

Ecological function zoning is a major mean to upgrade ecological functions. Its main purpose is to reveal laws of similarity and difference of natural ecoregion and rules of human activities' interference on ecosystem through application of ecology principles and methods, so as to lay a foundation for realizing difference management of natural and social elements and provide basic framework for spatial pattern construction of ecological secure environment. Different from natural division, it should consider not only natural environment characteristics and process, but also impact of human activities. Therefore, it is actually a unity of characteristic regionalization and function zoning.

Seeing from theoretical techniques and practice at home and abroad, main technical ideas of current ecological function zoning are still based on ecological suitability assessment and geographic information system platform. Make comprehensive suitability assessment through superposition of ecological suitability analysis of single factor and then divide ecological function areas. .

Following traditional ecological function zoning concept, in Pearl River Delta environmental protection strategic planning, the Pearl River Delta is divided into 3 first-level ecological function zones including ecological security barrier zone in ring-type mountain forest, urban agricultural economic zone in delta plain and ecological protection zone in southern coastal area, 7 second-level ecological function areas such as western ecological protection zone, biodiversity conservation area, etc., 75 third-level functional zones in land field like Dashahe Water Reservoir water conservation area and so on and 5 third-level functional regions along the coast.

Special Column 2: Ecological Function Zoning Practice of Xiamen

By collecting basic information of natural, economic and social elements related to coastal areas and neighboring sea areas in Xiamen city and selecting evaluation factors, formulate ecological suitability classification standards and weight for single factor. Obtain comprehensive suitability by superposition of single factor and then make comprehensive suitability classification standards in order to get suitability evaluation results.

Adopt Arcview platform to quantize all selected ecological factors (in accordance with electronic maps, charts and other data) and work out single factor coverage in light of following ecological suitability classification standards for single factor (Please refer to table 1.).

Ecological Suitability Classification Standards for Single Factor

Ecological Factor Classification Standards	5	4	3	2	1	Unit

Water Depth	-30～-20	-20～-15	-15～-8	-8～-5	>-5	m	
Bottom Material Type	uncharted type	sea mud	Sea silt soil (Classification value is 2.5.)		sea sandy soil	—	
Sea Area Ecological Environmental Quality	very bad	bad	medium	good	excellent	—	
Landscape Value	Extremely low value (Classification value is 4.5.)		Comparatively low value	Comparatively high value	High value	—	
Seacoast Population Density	>50	50～20	20～5	5～1	<1	one thousand people /km^2	
Rare Species Protection			Non-conservation areas (Classification value is 4.5.)		outside conservation areas for single species	outside conservation areas for multi-species	core conservation areas	—

According to ecological environmental sensitivity analysis, it can be divided into three functional areas, namely suitable, basically suitable and unsuitable functional zones; environmental protection is divided into three ecological function areas, that is, ecological management and protection district, ecological buffer zone and ecological reconstruction area.

Redefine ecological function areas of Xiamen by referring to ecological vulnerability analysis, ecosystem service function value assessment and existing ecological function zoning of Xiamen. It is generally divided into three levels with 3 ecological function areas in the first level, 8 ecological function subregions in the second level and 25 ecological function units in the third level (the left figure: distribution diagram of ecological function units of Xiamen).

5.3.4 Landscape Ecological Security Pattern Construction (Xiamen)

According to ecological security pattern theory of landscape ecology, there is a potential spatial pattern made up of some key parts, points and positional relations in landscape. It plays a pivotal role in the maintenance and control of ecological process of a certain system. A typical ecological security pattern includes: source, buffer areas, radiating routes, connections between sources and strategic points. Then potential landscape ecological security patterns in cities can be identified based on above theory.

Special Column 3:

Landscape Ecological Security Pattern Construction of Xiamen

- Source Confirmation: Extensive forest cover area and sea area in Xiamen are distribution areas of existing or potential native species, consisting the source of species diffusion and maintenance and deciding the stability of entire ecosystem. Northern forest land of Tong'an District and Jimei District, Caijianwei Mountain forest land in Haicang District, national scenic area----Wanshi Mountain in the south of the island and peripheral sea areas of Xiamen Island are all included in the planning.

- Determination of Potential Resistance Surface: Determine potential resistance surface of forest mainly in reference to distribution characteristics of topography and vegetation in Xiamen. Then seek other components of landscape security pattern in terms of distribution trend of resistance surface.

- Buffer Areas: composed of orchards and farmlands around forest cover area, also urban-rural ecotone.

- Radiating Routes: Strip parts radiating from source to outside parts through ridge lines and vast vegetation.

- Connections between Sources: There is one low resistance valley line or more between one source and other sources. Connection between sources which is an efficient channel and contact way between ecological flows can contribute to the formation of ecological corridors. To keep connections between sources is conducive to the stability of landscape ecological system.

The above parts, location and spatial relations of various strategic landscapes make up the landscape ecological security pattern of Xiamen.

After comprehensive consideration, landscape ecological security pattern of Xiamen can be planned as "one nuclear, four areas, 8 groups, triple corridors, seven ecological isolation belts and ten landscape strategies points" (the left figure: diagraming of landscape safety ecological pattern of Xiamen).

6 Technical Modules in Step 4: Prepare an Indicative Zoning Map for Green Land Protection

6.1 Module 4A: Identify and Map Forest Priority Areas

Purpose

Forest priority areas refers to areas with arbors, bamboos or shrubs, and coastal areas with mangroves, which include slashes, but exclude green space inside residential areas, forests within the range of railway or highway construction and forests to protect dikes of rivers and trenches.

Objective

Forest areas provide many environmental, social and economic benefits, including the absorption of pollutants and carbon dioxide, the production of oxygen, and recreational contact with nature. The objectives of this Module are to identify and map the type, diversity, character and ecosystem values of forests in the UREMP area.

Output

Measure and map the character and condition of forests and similar areas：

- Identify and map forest areas by type, character, diversity, etc. in the UREMP area.
- Identify and map forest areas in the UREMP area by their ecosystem，therefore provide comprehensive and credible input to planning decisions about the directions and nature of urban development and the distribution of land uses in the UREMP area.

Forest areas are divided into forest land, shrubs and others in terms of shade density and degree of coverage.

1. Sample plot survey

Adopt conventional coenological sample plot survey method to see into the quantitative characteristics of plant communities, including abundance, frequency, coverage of species (shade density of arbor and coverage of shrub and herb) and growth form (evergreen or deciduous trees) of species.

Abundance is observed by investigators directly and can be divided into five levels, namely a great many, many, still many, few and scare.

Frequency refers to the percentage of sample plots with certain creature in the total amount of sample plots.

Shade density refers to the ground coverage degree of arbor crown in a forest, reflecting density of stand. It is the ratio between vertical projection area of arbor crown and the total area of forest and is expressed with decimal fraction (1 for complete coverage). According to FAO (Food and Agriculture Organization of the United Nation), it is dense wood when shade density is 0.70 or above, medium dense wood when 0.20- 0.69 and open forest when less than or equal to 0.1- 0.20 (free of 0.20).

Coverage is expressed with percentage, referring to the ratio between vertical projection area of plants and the area where the plants are.

2. Species diversity index

Species diversity reflects the amount and structure of species in a community as well as respective amount of each species and the degree of uniformity, and the most used indices are Simpson index and Shannon-Wiener index.

Simpson index:

$$\mathrm{Ds} = 1 - \sum_{i=1}^{s} \frac{n_i(n_i - 1)}{N(N-1)}$$

Shannon-Wiener index:

$$\mathrm{H} = 3.3219(\mathrm{LgN} - \sum_{i=1}^{s} n_i Lgn_i)$$

Therein, n_i stands for the number of species i and N stands for the amount of all species.

3. Ecosystem values

The ecosystem values of forest areas include water and soil conservation, water source regulation, wind prevention and sand fixation.

a) Water and soil conservation, one of the key regulation services provided by forest ecosystem, is realized through reduction of ablation-resulted soil erosion, relating to climate, soil, topography, vegetation, etc. The water and soil conservation function of forest ecosystem is assessed with sol conservation amount, namely the difference between potential amount of soil erosion and actual amount of soil erosion.

The water and soil conservation service model, a revised version of USLE (universal soil loss equation), is adopted for the assessment.

Model structure: $A_c = A_p - A_r = R \times K \times L \times S \times (1 - C)$

Therein, A_c is the amount of soil conservation, A_p is the potential amount of soil erosion, A_r is the actual amount of soil erosion, R is the precipitation factor, K is the soil erosion factor, L and S are terrain factors and C is the vegetation cover factor.

R- precipitation factor

$$R = \alpha[(\sum_{i=1}^{12} P_i{}^2)/P]^{\beta}$$

In the formula: P_i is the monthly average precipitation, P is the annual average precipitation, α= 0.3589, β= 1.9462.

K- soil erosion factor

$$K = f_{csand} \times f_{c1-si} \times f_{orgc} \times f_{hisand}$$

$$f_{csand} = 0.2 + 0.3\exp[-0.0256\mathrm{ms}(1 - \mathrm{msilt}/100)]$$

$$f_{c1-si} = [msilt/(mc + msilt)]^{0.3}$$

$$f_{orgc} = 1 - 0.25orgC/[orgC + \exp(3.72 - 2.95orgC)]$$

$$f_{hisand} = 1 - 0.7(1 - ms/100)/\{\left(1 - \frac{ms}{100}\right) + \exp[-5.51 + 22.9(1 - ms/100)]\}$$

In the formula: ms is grit content, msilt the silt content, mc clay content and orgC organic carbon content.

L, S- terrain factors

$$L = (\lambda/22.013)^m$$

$$S = 10.8 \sin\theta + 0.03 \qquad \theta < 5°$$

$$S = 16.8 \sin\theta - 0.5 \qquad 5° \le \theta < 10°$$

$$S = 21.91 \sin\theta - 0.96 \qquad 10° \le \theta$$

Here, λ is slope length (m), m is slope length index, θ is the grade of slope (°).