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Review

Key Considerations for the Use of Nature-Based Solutions in Climate Services and Adaptation

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Abstract: Nature-based solutions (NbS) involve the reliance on natural or nature-based systems to enhance community resilience through delivering both climate adaptation and mitigation outcomes. While NbS do not necessarily represent new "technology" or methods, the intentional incorporation of these approaches into climate adaptation and mitigation efforts is often considered novel, particularly within the climate services sector where interventions have historically prioritized structural infrastructure approaches. NbS can offer an effective replacement for or complement to such traditional infrastructure approaches. Additionally, natural and nature-based systems can respond to climate change in a manner that engineered solutions often cannot, providing long-term holistic adaptation and mitigation success with additional benefits to ecosystem services such as improved air and water quality, carbon sequestration, outdoor recreation, and biodiversity protection. The incorporation of NbS as a core component of climate services increases the likelihood of adoption and effective implementation, ensuring greater long-term effectiveness for both communities and the natural systems on which they depend. This article supports the adoption and effective implementation of NbS by climate service providers through presenting a set of seven "key considerations" for their use in community-based adaptation. These key considerations are based on a review of work in the field to date, both within the United States and globally. Although these key considerations were developed in support of US adaptation planning applications (specifically, the US Climate Resilience Toolkit), they have global relevance.

Keywords: climate services; nature-based solutions; vulnerability assessment; climate adaptation; resilience; co-production

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1. Introduction

As the pace and scale of climate change and its impacts become increasingly evident across the United States and globally, there is a growing need for robust and reliable climate services, which can be defined as the provision of climate information for use in decision making [1]. Climate data from across multiple sensors and observation platforms document increasing climate variability, including changes in temperature and precipitation patterns, more extreme weather events, and rising sea level. The number of billion-dollar weather and climate disasters in the United States has doubled from about five events per year in 1990–1999 to close to 13 events annually in 2010–2019, with losses exceeding 900 billion USD in these last 10 years [2]. These climatic changes and their associated impacts are affecting our water systems, biodiversity, food supply, and health with far-reaching consequences for US communities and ecosystems [3]. As these climate impacts become even more disruptive in the future, the approaches to mitigate these risks will require novel thinking that moves away from business-as-usual strategies such as traditional structural solutions (e.g., levees, sea walls, and stormwater drainage channels). In the face of accelerating climate change, the limitations of such hard infrastructure approaches—high costs, limited lifetime, risks of maladaptation—are becoming all too evident [4]. Such static structures, which are often designed to standards based on past climatic conditions, may not be able to keep up with the increasing climate variability and, accordingly, may have escalating maintenance costs. A lack of community or ecological co-benefits and, in many cases, negative or maladaptive consequences can make them an unsuitable adaptation solution in certain circumstances.

The role of nature, on the other hand, is receiving increasing attention for coping with growing climate risks, and the International Union for Conservation of Nature (IUCN) has published several reports designed to define and operationalize the concept of nature-based solutions (NbS) [5,6]. The concept of NbS builds on the framework of "ecosystem services", which, over the past few decades, has emerged as an important approach for understanding, documenting, and valuing the varied contributions of nature to people [7,8]. By providing protective benefits, NbS nest within the "regulation of environmental processes" category of ecosystem services as defined by the Intergovernmental Panel on Biodiversity and Ecosystem Services [8]. Nature-based solutions can offer effective approaches for addressing climate vulnerabilities and reducing risks through replacing or complementing traditional infrastructure approaches [5]. Additionally, natural and nature-based systems can respond to changing climatic conditions in a manner that engineered solutions often cannot, offering long-term holistic adaptation and mitigation outcomes [4,9,10].

Nature-based solutions are rapidly becoming a core component of what US climate service providers can offer to communities in support of their adaptation and resilience planning and implementation efforts. This review is, therefore, intended to help climate service providers understand the conceptual basis for NbS and explore a set of key considerations for the broader application of NbS in community-based adaptation and resilience planning. Specifically, the aim of this review article is to support increased or improved adoption and implementation of NbS in climate services to effectively reduce climate change impacts. This is accomplished through two main objectives. First, the article presents seven key considerations designed to guide climate service providers in the US through the process of incorporating NbS into community adaptation planning. Second, the article highlights factors required to be considered by climate service providers to help them embed these considerations across different levels and users of the climate service process. These key considerations stemmed from literature reviews, organizational expertise, and discussions with adaptation practitioners, and were developed in support of the US Climate Resilience Toolkit [11]. Although our focus here is on US applications and adaptation planning, these key NbS considerations have global relevance.

In general, climate services tend to focus on making climate information more available and accessible for decision makers at all levels, as well as filling data gaps as they arise and demand is identified. One of the greatest challenges for the uptake of NbS is their limited integration into existing climate services and use by climate service providers. Therefore, among the first steps in better integrating NbS will be to broaden the information scope of climate services and climate service providers to share NbS-relevant data and options in support of adaptation. Existing climate services frameworks already offer avenues through which the integration of NbS could be explored at each level of the climate service process. For instance, each component of the Global Framework for Climate Services proposed by Hewitt et al. [12]—users, user interface platform, climate services information system, observations and monitoring, and research, modeling, and prediction—can incorporate multiple nature-based considerations. Starting with ensuring that natural systems are included in observation and monitoring to designing research and models that can generate NbS-relevant projections is essential to creating a climate services information system that not only considers NbS (and natural systems more broadly) in its process but can also provide easily discoverable information (through a user interface platform) relevant to NbS so that users can apply the outputs to NbS implementation. Across all of this is the need to increase capacity of users and service providers at each level in order to expand skills and knowledge related to NbS.

As climate service providers support partners in developing adaptation strategies, there are many opportunities to incorporate NbS, including as part of hazard mitigation/risk reduction, restoration, and infrastructure development, and ensuring the sustainability of ecosystem services (e.g., water quality and quantity, and carbon sequestration) [9,10,13]. Indeed, NbS may often be able to address multiple climate stressors (temperature, flooding, drought, and sea level rise) in support of multiple local goals with less directed long-term management. For example, floodplain protection and/or management is an NbS that incorporates well into hazard mitigation planning to address flood impacts. Similarly, integration of vegetation buffers (e.g., forests and riparian habitat) around and through communities can serve to reduce flood risk, ameliorate thermal stress, and support ecosystem services (water quality, air quality, wildlife, and recreation), as well as aquifer recharge. Furthermore, NbS can level the playing field by offering more affordable, sustainable adaptation solutions, making them a particularly useful option for climate service providers to share with partner communities.

2. What Are Nature-Based Solutions

"Nature-based solutions" (NbS) refer to the use of natural systems and processes to deliver a variety of environmental benefits, especially for climate adaptation/resilience and climate mitigation goals. These strategies can range from planting trees and installing rain gardens in urban areas to provide shade and reduce stormwater flow to restoring rivers and floodplains to reduce flood risks and improve water quality. NbS include a broad range of strategies, from conservation of intact natural systems and restoration of priority ecosystems to the use of engineered systems designed to mimic natural system functions [10]. They also include nonstructural solutions such as open-space preservation through buyouts and easements. Nature-based strategies can complement structural solutions to form hybrid or "green/gray" systems for climate adaptation and risk reduction.

The International Union for the Conservation of Nature (IUCN) defines NbS as " . . . actions to protect, sustainably manage and restore natural and modified ecosystems in ways that address societal challenges effectively and adaptively, to provide both human well-being and biodiversity benefits" [5].

This broad conception of NbS encompasses or intersects with several related terms and approaches, as noted above. This includes terms that completely overlap with the NbS concept (e.g., natural defenses, natural infrastructure, and ecosystem-based adaptation), as well as terms that are a subset of NbS tailored to a specific concern (e.g., green infrastructure (for stormwater management) and natural climate solutions (for carbon sequestration)). Preferred terminology may depend on the specific sector, community, or location. For instance, the term natural infrastructure often resonates with planners and policymakers accustomed to working with traditional gray infrastructure; accordingly, this NbS-related term is often used in federal and state policies and funding authorizations. The framing of NbS can also influence public perception and policy choices, which can lead to both ambiguity and overly narrow conceptualizations, thereby sometimes enabling practices with negative consequences for biodiversity and people [14,15]. The seven key considerations presented below are based on a broad conception of NbS and designed to reduce such ambiguity and overly narrow characterizations in order to promote the effective incorporation of the concept in climate services and adaptation more generally.

3. Key Considerations for Incorporating Nature-Based Solutions

In 2020, the IUCN published a collaboratively developed global standard for the design and application of NbS, offering a common framework for increasing the scale and impact of these approaches while seeking to avoid inconsistent and ungrounded applications of the concept [6]. Although the IUCN standard reflects a significant advance in mainstreaming NbS globally, the structure of that standard (eight criteria and 28 associated indicators) is highly conceptual and may not meet the practical needs of US climate service providers and their local community adaptation clients. Building on that standard, this paper proposes seven "key considerations" for the use of NbS (Figure 1) that can be embedded in existing climate services, products, and frameworks at the local and regional levels. Through incorporating these considerations, the field of climate services can expand the scope and relevance of its support for community-based adaptation clients and other users.

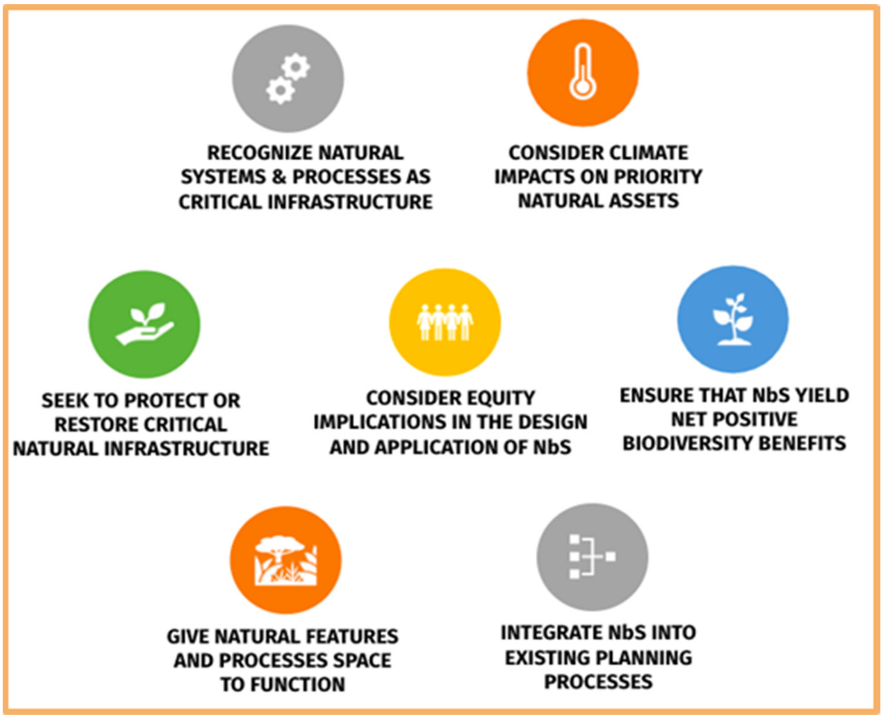

Figure 1. Key considerations for use of nature-based solutions.

3.1. Recognize Natural Systems and Processes as Critical Infrastructure

Climate service providers working through an adaptation planning process with communities typically focus first on project scoping, which includes identifying key community assets and critical infrastructure (e.g., schools, hospitals, emergency services, power plants and other utilities, and levees and seawalls). Because damage to or loss of these structures and the services they provide would have significant impacts on the health and safety of the community, these structures and services are typically priorities for protection from climate-related hazards. Although they are often not included within inventories of critical community assets, natural systems such as forests, rivers, floodplains, tidal wetlands, and coral reefs also provide crucial benefits and services to human communities, including protection from natural hazards such as flooding, erosion, and extreme heat [4,10,16–19]. The essential ecosystem services provided by natural systems also include other social, economic, and cultural benefits such as freshwater supplies, improved air and water quality, provisioning of food and other resources, pollination services, and recreational opportunities, as well as the nonmaterial benefits (e.g., cultural, spiritual, and aesthetic value) provided by natural ecosystems [5,20].

Many community benefits and ecosystem services provided by natural systems cannot be easily replaced by engineered structures, which can be costly to build and maintain and provide fewer additional benefits compared to functioning natural systems. For instance, living shoreline projects use natural techniques to stabilize shorelines, providing wave attenuation that buffers storm surge while also supporting birds, marine life, and local recreational opportunities, often costing less than conventional shoreline armoring techniques [21–23]. Some benefits provided by natural systems may also be difficult or impossible to replace once the natural system is degraded or lost. For instance, large-scale loss of forest cover can also result in significant alterations in local or regional hydrology, with resulting implications for community water supplies and water quality [24]. In many instances, the protective functions and other ecosystem services provided by these systems are likely to become even more critical as the climate changes, exacerbating coastal erosion, extreme heat events, water shortages, biodiversity loss, and other stressors impacting community safety and wellbeing [17].

For climate service providers, working with a community to identify critical natural systems/assets and features is essential for supporting climate adaptation, including the design and implementation of NbS. Practitioners can draw from a range of information sources to identify the natural systems and processes that comprise a community's natural assets, such as existing planning documents, local inventories, remote sensing, and community knowledge. Employing a range of methods results in a comprehensive understanding of natural assets that extends beyond designated parks and recreational infrastructure (e.g., piers and nature trails) to also include wetlands and waterways, riparian buffers and floodplains, urban tree canopies, and wildlife habitat corridors. During this process, it is important for climate service providers to help communities explore the full range of co-benefits and ecosystem services that natural assets can provide (e.g., climate regulation, storm surge protection, and job opportunities), as these may not have been previously discussed or identified as valuable by community members. For instance, a flood-prone community losing mangroves to development or expanding shrimp aquaculture may not be appropriately valuing the role of mangroves in flood and erosion control and as a nursery habitat that supports recreational fishing. The process of identifying natural systems and the critical services they provide to the community can also serve as an opportunity for community members to come together and build relationships that will support collaborative planning and implementation of specific NbS projects within the community. For climate service providers, the discussions that occur in these settings can illuminate community values and interests, paving the way for meaningful stakeholder engagement.

3.2. Consider Climate Impacts on Priority Natural Resources

The ability of natural systems to respond to disturbances by withstanding or recovering from the disruption, as well as past exposure leading to existing adaptation to such stresses, is one aspect of why NbS are attractive to communities as part of their adaptation planning [10,25]. For example, transport and deposition of sediments from higher up in the watershed results in accretion of soils in downstream wetlands and estuaries. This may provide enough additional land to replace erosional loses after storms or match land loss due to sea level rise [25,26]. However, climate change is likely to challenge ecosystems, making even intact, disturbance-adapted systems vulnerable to rapidly changing conditions and climate extremes. Ecosystems that have been altered or degraded by human land uses or activity are generally even more vulnerable to climate impacts, as anthropogenic stressors reduce the natural adaptive capacity of those systems to respond to and cope with change [10]. For example, urban encroachment and upstream dams can limit the natural movement of sediment into tidal marshes, preventing natural accretion and reducing their resilience to storms and sea level rise [27]. As a result, the vulnerability of human communities to the impacts of climate stressors and extreme climate events cannot be considered in isolation from how natural systems are affected by climate change. In doing so, the protective benefits and ecosystem services provided to those communities by natural systems could be overestimated. Evaluating both natural systems and human community vulnerabilities together allows for identifying where existing and intact natural systems are more likely to continue to deliver protective benefits and services, as well as where this may not be the case, requiring either additional assistance to restore ecosystem functioning or non-NbS solutions. Therefore, it is essential that climate services are inclusive of data and resources that also explore the implications of climate change for these natural systems.

The process of understanding how natural ecosystems are likely to be affected by climate change is typically accomplished through assessing the vulnerability of these resources [28]. A vulnerability assessment can support community adaptation planning through the following approaches:

- Identifying which priority natural assets are most and least likely to be impacted by current and projected climate conditions;
- Understanding why priority assets are vulnerable to inform the identification of possible adaptation actions that can reduce vulnerabilities and climate risks;
- Determining when and how to most effectively implement adaptation actions targeted toward priority natural assets.

Numerous approaches exist to assess the climate-related vulnerabilities and risks to species and ecological systems [28]. Just as all adaptation is local, selecting the right vulnerability assessment process is also dependent on the locality (e.g., resources present, detail required, data availability, and resource availability). When considering the climate change vulnerability of natural systems, climate service providers should seek to use the most ecologically relevant climate variables (which often may involve extremes rather than averages) and multiple future scenarios. Relying on ecologically relevant facts can provide the most accurate picture of ecosystem responses, but can be complex and may not necessarily be supported by the most widely accessible climate datasets. Ultimately, understanding the components of the vulnerability of ecosystems their associated species is essential to creating and implementing adaptation strategies that will successfully benefit human communities.

3.3. Consider Equity Implications in the Design and Application of NbS

Natural assets can be important to communities, offering valuable options for reducing climate risks and enhancing their overall wellbeing and resilience. However, NbS can also magnify existing inequities and/or create new challenges within a community. Historically, natural features such as parks, nature trails, and green spaces have benefitted predominantly white and more affluent communities [29]. Even when natural infrastructure is prioritized in low-income communities and communities of color, historical disinvestment and underinvestment in those same communities can make natural infrastructure projects less equitable. In Baltimore, Maryland, several smaller natural infrastructure projects installed by nongovernmental organizations and community groups have been predominantly located in areas with higher African-American populations that are less likely to have larger, city-funded projects. As compared to large-scale city-funded projects in neighboring communities, these non-city-led projects are limited to small rain gardens or micro-bioretention facilities [30].

Certain nature-based approaches such as creation of green spaces and floodplain acquisitions can also create new challenges and increase risks for socially vulnerable populations. Creating green spaces and other urban greening programs can increase housing costs and property values with several factors such as location (e.g., distance from downtown), scale, and function affecting whether a place gentrifies, risking displacement of the community members these strategies are intended to benefit [31]. Nonstructural solutions such as flood buyouts also commonly benefit whiter, wealthier, and more urban communities, although lower-value properties and properties owned by communities of color are more likely to accept and be bought out than higher-value properties through these programs [32].

Designing and implementing equitable NbS efforts are crucial to break the patterns of existing and historic inequities and build the adaptive capacity of socially vulnerable and marginalized communities. Natural and nature-based features, when prioritized in at-risk, socially vulnerable communities, can effectively address climate risks for these communities, as well as substantively contribute to an improvement in quality of life for community residents. Strategies such as inclusive and collaborative planning, partnership with tribal, indigenous, and other natural resource-dependent groups, and meaningful outreach and education can support representative NbS planning and implementation.

The effectiveness of climate products and services hinges on how well they center the needs of different users, particularly underrepresented and marginalized groups. This will require climate service providers to engage diverse stakeholders (e.g., community-based organizations) and co-produce products (e.g., risk assessments and adaptation action plans) that address user needs. Adaptation options driven by equitable and inclusive climate services will not only expand the usability of climate services by decision makers and public agencies, but also lead to more just outcomes in climate-resilient communities.

3.4. Ensure That NbS Yield Net Positive Biodiversity Benefits

Nature-based solutions should enhance biodiversity value and yield net biodiversity benefits, for instance, through incorporating site-specific designs and materials. Biodiversity includes multiple levels of biological organization—from genes and species to ecosystems—and each level of organization can be understood as consisting of three major components: composition, structure, and function [33]. NbS, depending on the type of project, may rely on one or more of these levels or components, for instance, a particular species (i.e., composition), habitat (i.e., structure), or biological processes (i.e., function). Strategies such as tree plantings using native and climate-resilient species, beaver reintroductions to restore wetlands and riparian areas, and living shorelines that use oysters and marsh grasses to stabilize coasts both offer protective benefits and strengthen long-term ecosystem resilience.

Natural ecosystems and native species are already under stress from a variety of anthropogenic sources, which, in many instances, has significantly reduced their natural adaptive capacity. Climate change is adding another layer of threats to already sensitive species or degraded systems, sometimes directly (e.g., higher temperatures and increasing drought) and, at other times, by exacerbating existing stresses. Addressing the species and ecosystem impacts of climate change, through targeted adaptation actions and climate-smart conservation practices [34], is essential to sustaining NbS functions. In doing so, it is important to seek net positive biodiversity and ecological outcomes, which not only slow ecological deterioration but also achieve actual ecological enhancement in value and function. Understanding climate change impacts on biodiversity, both spatially and temporally, will influence these decisions. In certain cases, priority habitats (e.g., sites containing the sole remaining populations of endangered species) will require an immediate emphasis. Similarly, areas where the effects of climate change are likely to be buffered and, therefore, hospitable for the lasting survival of particular species, also known as climate change refugia, may be useful to protect and prioritize.

Climate services offer an opportunity to embed biodiversity conservation outcomes in NbS design and implementation efforts. The recently released IPBES Values Assessment [35] highlights the current dominant, yet narrow, focus on short-term profits and economic growth when valuing nature in decision making as a key driver of the global biodiversity crisis. Climate service providers can help broaden this focus by bringing a holistic understanding of ecological values and services in the design and implementation of NbS. This can be achieved by embedding a combination of biodiversity data, local ecological knowledge, and multiple stakeholders throughout the generation and provision of climate service products. Additionally, continuous monitoring and evaluation of NbS to account for ecosystem uncertainties and climate impacts can mitigate unintended consequences, as well as inform future efforts to enhance the functionality and connectivity of ecosystems to achieve net biodiversity enhancement [36,37].

3.5. Seek to Protect or Restore Critical Natural Infrastructure

Intact natural systems are themselves at risk of climate change. Along the Gulf of Mexico, coastal ecosystems such as beaches and dune systems, offering protective benefits to nearby communities, are susceptible to erosion and conversion to open water due to sea level rise and saltwater intrusion [38]. Similarly, rangelands in Arizona, which offer habitat for an array of wildlife species, are experiencing mass mortality events due to more frequent and severe periods of droughts and climate change-fueled wildfires [39].

Protecting and restoring critical natural infrastructure will be essential adaptation strategies to help ensure that such systems will continue to provide ecosystem services and community benefits. This can involve prioritizing the protection of intact natural systems, restoration of degraded systems, incorporating nature-based features in engineered systems, and/or integration of natural (green) and engineered (gray) approaches in hybrid infrastructure. Protecting existing biodiversity and still extant natural systems should be a priority, but restoring the composition, function, or structure of already degraded ecological systems is becoming increasingly important for achieving adaptation and mitigation outcomes through NbS. In an era of rapid climate change, ecological restoration should not be viewed solely as a return to prior or historical states, but rather in the context of sustaining ecological function under current and future conditions. The International Standards for the Practice of Ecological Restoration [40] provides such a framework for guiding the development and implementation of ecological restoration projects. Ultimately, protection and restoration efforts will need to be taken in the light of broader climatic changes where the focus lies not just on preservation and restoration to historical conditions (i.e., managing for persistence), but one that is simultaneously open to anticipating and actively facilitating ecological transitions (i.e., managing for change) [34].

Climate services will need to integrate and embed ecological knowledge, as well as natural resource expertise to provide the required context for nature-based adaptation decisions. This includes efforts such as risk mapping and impact modeling for vulnerable ecosystems based on long-term climate and ecological datasets. Such integrated data serves as a useful climate service product for ecological and natural resource scientists and managers, planners, and representatives from federal, state and local agencies (e.g., fish, wildlife, and parks departments), conservation organizations, tribal and indigenous groups, equity-centered organizations, and others to share technical expertise, datasets, and knowledge of the region's natural resources.

3.6. Give Natural Features and Processes Space to Function

By nature, most intact ecosystems are dynamic and possess at least some ability to respond to change over time [25]. For example, coastal dune systems that are unrestricted by the presence of roads or development are constantly shifting as wind and waves move the sand, allowing them to naturally migrate inland as sea levels rise [41,42]. Rivers, wetlands, forests, and grassland systems all also have the ability to respond to environmental changes, through varied mechanisms such as sediment accretion (or erosion) and shifts in vegetation communities, among others [43–45]. In general, the systems that offer the most significant protective benefits to human communities are often those that have evolved to cope with a wide range of conditions and/or rapid fluctuations in environmental conditions, and so are well adapted to absorb the impacts of extreme weather and other climate-related hazards without significant degradation to the system or surrounding areas. However, in many places, human land uses have altered or constrained natural systems, preventing them from absorbing and responding to change and increasing exposure of surrounding communities to climate-related hazards such as flooding. For example, floodplains are well equipped to capture and hold excess stormwater, allowing it to be absorbed slowly and preventing downstream flooding [46]. Unfortunately, floodplains are often highly valued for development, and, where this occurs, the flood protection and erosion control benefits of this system are lost for surrounding natural and human communities, as well as those that lie downstream [47,48]. Furthermore, as climate change increases the frequency and severity of extreme precipitation events, inappropriate siting of new infrastructure and development is likely to cause even greater risks or create new hazards in areas that were not previously vulnerable to flooding.

Well-functioning natural systems also include complex processes that operate across a variety of spatial and temporal scales, such that what happens in one area may be inextricably tied to the functions of adjacent systems or more distant locations. For example, streamflow volume and water quality in a given stream reach is heavily dependent on the surrounding land uses, both upstream and in neighboring upland and riparian areas that absorb and filter runoff [49,50]. As a result, successful implementation of NbS designed to address flood risk or water quality issues would need to consider both the impacts of climate change and the hoped-for benefits of NbS at the watershed scale and not just the community scale.

Climate service providers supporting communities in expanding the use of NbS for hazard reduction and other co-benefits must think in terms of larger ecosystem scales and processes in order to ensure that natural systems have the space that they need to function. This becomes even more important as the climate changes and natural systems are responding to more extreme conditions, which may necessitate protection, restoration, or creation of systems or consideration of natural processes that extend across larger areas. In contrast to non-NbS approaches that require human intervention for modifications or adjustments (as well as constant maintenance), NbS designed at appropriate spatial and temporal scales have the potential to respond to changing conditions while still delivering desired ecosystem services.

3.7. Integrate NbS into Existing Planning Processes

The easiest way to include NbS is to simply adopt these measures as part of existing planning processes. This includes integrating climate-smart solutions into legally required land-use planning efforts, such as comprehensive or general plans, multi-hazard mitigation plans, community/neighborhood plans, and utility plans, as well as climate action plans that may or may not be required in any given jurisdiction. NbS as presented in the examples in this paper, can be offered by climate service providers as components of these plans that reduce climate risk, with the added potential benefits of reduced long-term maintenance cost, less direct management, possible autonomous improvement, and the support of associated ecosystems and their services.

To those ends, there is opportunity, heretofore underutilized, to include NbS as key climate change adaptation elements in traditional local planning processes. For example, aspects of each of the many elements of a local comprehensive or general plan (e.g., housing, transportation, public facilities, and environment) are vulnerable to climate change [51], and there is opportunity to incorporate NbS into planning for each of these sectors to reduce those vulnerabilities.

While NbS can be incorporated into almost any local planning process, there are also opportunities to build local capacity and uptake of NbS through the participants in those processes. This may require engaging multi-solution climate service provides, rather than just hard infrastructure-focused engineering firms, in order to focus on developing more holistic solutions that include NbS. At the same time, local community desires to include NbS could increase climate service provider awareness, and NbS-interested stakeholders included in local planning processes could increase community ability to implement NbS. For example, including natural resource managers and environmental justice stakeholders with natural system interests will help to identify opportunities for NbS that can support the needs of both nature and local communities.

As previously mentioned, climate services may also need to include additional information to support fully integrating NbS into local planning. For example, the data needed to understand the scope of local impacts and vulnerabilities may require different components (e.g., stream flow and timing, soil temperature, and species composition) at different scales (e.g., watershed and seasonal/decadal) with different thresholds (e.g., extremes and timing/phenology).

4. Conclusions

Given the vital role of climate services in delivering support to local entities in their efforts to develop effective community-based adaptation plans, ensuring that NbS are fully integrated into climate service offerings will be essential for achieving successful adaptation and mitigation outcomes. The seven "key considerations" outlined above are designed to guide the inclusion of NbS into local planning processes, resulting in improved adoption of climate adaptation actions that are sustainable for both communities and the ecosystems around them. In addition, designing and implementing NbS on the basis of these key considerations can offer adaptation solutions that may be less expensive and less fragile than comparable gray infrastructure options.

Climate services are meant to provide useful and usable climate information in a timely and tailored manner to support adaptation. To date, climate services have been envisioned to focus on delivery of climate data (e.g., temperature, precipitation, and sea level rise), socioeconomic data, vulnerability assessments, and guidance to assist users (individuals and decision makers). However, existing climate service frameworks can be improved and informed by inclusion of nature-based adaptation solutions in general and incorporation of these NbS-specific key considerations. With growing interest in and need for the use of natural and nature-based approaches for climate risk reduction, it is necessary to more explicitly embed NbS within the framework of any climate service to ensure the intended benefits of these services to all users.

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