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Translating Nature-Based Solutions for Water Resources Management to Higher Educational Programs in Three European Countries

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Abstract: Climate change has increasing impacts of hydro-meteorological extremes on water resources. Projections indicate a similar trend and challenge in the effectiveness of conventional engineering solutions in climate change adaptation (CCA) and disaster risk reduction (DRR) strategies. Nature-based solutions (NbSs) have been promoted as viable approaches and measures that complement engineering solutions. While the effects of NbSs have been increasingly demonstrated, their broader implementation can be favoured by NbSs knowledge integration in higher education curricula. Knowledge on how the research practice is translated into the educational landscape is missing. This paper adopts the concept of knowledge translation and analyses the integration of NbSs in the study programs of higher education institutions in three European countries (Croatia, Czechia, and Slovenia). Specifically, it explores the extent, thematic areas, and curricular settings of NbSs related to water resources management in implemented curricula at public universities. The results show that NbSs are integrated in a limited number of courses within the relevant study programs (in the fields of, e.g., natural sciences, geography, and engineering and technology) and represent rather an extension of compulsory curricula. Bibliometric analysis revealed that most courses involving the NbSs approach still represent a personalized knowledge, i.e., developed by professors during their research activities. The barriers impairing a broader integration of NbSs in the studied programs are then discussed. Our results therefore indicate that NbSs do not represent a mainstream knowledge that would proliferate into higher education curricula through accreditations procedures, but that the knowledge that is mostly integrated through direct incremental implementation of NbSs in the individual compulsory lessons or facultative courses. We assert that without broader and systematic NbSs knowledge translation to study programs, the effectiveness of climate change adaptation and disaster risk reduction strategies cannot be fully achieved.

Keywords: nature-based solutions (NbSs); water resources management; higher education; curricula; knowledge translation; bibliometric analysis

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1. Introduction

Scientific and technological achievements since the 19th century have enabled the application of numerous successful engineering solutions to address water management problems. In recent decades hydro-meteorological extremes, such as floods, droughts, and heatwaves, have intensified due to climatic shifts [1]. These extreme events are exacerbated by human activities and land use changes, from rapid urbanization to agricultural practices, and present a significant threat to socio-ecological systems [2,3]. Such changes challenge

the effectiveness of conventional engineering solutions. Climate change projections indicate an increasing risk of hydro-meteorological extremes. This necessitates robust climate change adaptation (CCA) and disaster risk reduction (DRR) strategies, which will engage with novel approaches to water resources management [4]. Blue and green infrastructure (GI) and ecosystem-based adaptation (EbA) are just a few examples of approaches developed under the nature-based solutions (NbSs) umbrella. NbSs have already proved to be capable of complementing conventional engineering approaches when addressing climate-related challenges in water resources management along with preserving biodiversity and providing a variety of other ecosystem services [5].

NbSs were defined by the European Commission as 'actions inspired by, supported by, or copied from nature' [6]. NbSs include multiple disciplines, such as environmental and civil engineering, geography, environmental economics, or agroforestry. A systematic review by Sowińska-Świerkosz and García [7] on multiple NbSs definitions concluded that associated measures '(1) are inspired and powered by nature; (2) address (societal) challenges or resolve problems; (3) provide multiple services/benefits, including biodiversity gain; and (4) are of high effectiveness and economic efficiency'. Sustainable water resources management using the NbSs approach is recognized as an effective means to achieving sustainable development goals (SDGs) [8,9]. NbSs are supported by the European Union (EU) through several frameworks, such as the Water Framework Directive, Floods Directive, Habitats Directive, Birds Directive, Europe 2020 strategy—resource efficient Europe, Blueprint to safeguard Europe's waters, The Biodiversity Strategy including the Green Infrastructure strategy, and Climate Change Adaptation Strategy. The EU promotes initiatives and research projects to implement NbSs for water resources management and hydro-meteorological risk reduction, namely through the Green Deal. In recent years, such initiatives and projects have been launched [5,10,11], but broader implementation of NbSs at the national level still depend on the individual countries' policies and their specific natural resources and environmental priorities.

Despite the increasing promotion of NbSs there are still multiple limitations associated with the implementation of this approach [12]. For example, the implementation of NbSs is often met with resistance from planning departments due to institutional dependencies associated with the use of grey infrastructure measures in the past [13]. In addition, some countries often use ad hoc instruments that are deployed immediately after disastrous events and usually do not provide incentives to reduce future damages, while NbSs often require more strategic planning [14]. In addition, the effectiveness of many NbSs is not properly monitored and evaluated [15]. There is a potentially limiting impact of small-scale measures with increasing severity of hydro-meteorological events, especially at large flood or drought events. As a result, it is difficult to determine whether NbSs have significantly reduced, e.g., the peak discharge. Additional barriers, such as lack of political will, current land use and property regulations, and different financial and institutional arrangements in the relationship between NbSs and flood risk management were identified by Raška et al. [12]. Despite NbSs being implemented at European and national legislations, promoted by some of the EU missions, such as the Adaptation to Climate Change and A Soil Deal for Europe, and several ongoing research projects on NbSs validation, there is clearly a lack of knowledge transfer from research to every-day professional practice.

Among the important, but so far rather neglected, explanations for a resistance toward broader implementation of NbSs in water resources management is a cognitive lock-in in professional planning practice [13]. The rather limited implementation of NbSs is favoured by poor knowledge translation from existing fundamental and applied research practice to national higher education curricula [16] that educates prospective professionals. The knowledge translation problem was recently addressed by emphasizing the potential of a triple helix among university, government, and industrial sectors [17]. It was argued that poor knowledge translation is underpinned by different expectations and practices held by researchers, on one hand, and practitioners and policy makers, on the other. This 'two cultures problem' [18] then maintains a research–practice gap in the long-term. Here

we argue that expectations about the core knowledge pertinent to individual knowledge domains may result in marginalization of certain discourses, such as NbSs, or in their delayed implementation into the higher education curricula.

The OECD [19] has widely discussed the barriers to knowledge translation that contribute to the limits in educational innovation. They point out the contradictory views held by policy makers, who complain about curricula rigidity and path-dependence, on the one hand, and by educators, who point to the prevailing top–down approach and limited co-creation in curricula development, on the other hand. Burrill et al. [16] show that the lack of co-creation may also rest in a limited role of research in developing curricula. For higher education curricula, this picture may be slightly different, however, since many educators are in the forefront of knowledge creation, i.e., conducting fundamental and applied research. The reasons for not implementing the full-range knowledge of NbSs to the curricula may then rest also in other barriers, such as disciplinary epistemological traditions [20] and institutional arrangements respective to the field of education. This therefore extends the above noted 'two cultures problem' and delves deeper in disciplinary traditions at universities. Yet, these have been only scarcely subject to a critical analysis. The question therefore is whether the widely discussed lack of knowledge translation can also be seen in the implementation of NbSs into university programs and thus contributes to certain inertia of conventional water resource management approaches in practice.

To address this research question, we define the following research aims for this paper. First, we aim to reveal to what extent recent theoretical and practical research advancements in NbSs are translated to higher education curricula. To address this research question, we specifically analyse the implemented curricula, which denotes the actual teaching and learning activities that are explicitly included and applied in the study programs [21]. This is in contrast to available the curriculum, which describes all available resources and competencies that are planned for the particular study programs, but that the educational practice may fail to implement effectively. We then ask whether NbSs constitute compulsory parts of the curriculum, and whether there exist differences or common approaches across countries and fields of education. To support the analysis, we use bibliometric mapping to identify core clusters and authorship of current NbSs research in three countries and we look into individual associations between the higher education courses and the publishing landscapes. Based on these findings, we review and discuss the pathways through which new knowledge in NbSs is translated to higher education study programs and whether these pathways may have a variegated effect on programme content. Finally, we summarize the lessons that can be drawn from the current development to support knowledge translation and decrease the 'research–practice' gap in using NbSs for water resources management. These research aims and questions have been pursued in three European countries, namely Croatia, Czechia, and Slovenia. These countries cover different regional environmental domains defined in [12], but they also ensure comparability and coherence in the findings in terms of the institutional setting. The unifying feature of the case studies is their location in a central European setting affected by educational transformation after the fall of communism in late 1980s.

2. Institutional Setting in Higher Education

2.1. Croatia

Higher education in Croatia is conducted in public universities (8), private universities (3), and other higher institutions (32), including professional studies, such as polytechnics, and it is regulated by the Act on Higher Education and Scientific Activity [22]. The initial accreditation and re-accreditation of study programs in Croatia is regulated by the Act on the Quality Assurance in Higher Education and Science [23] and it is performed by AZVO (Agencija za znanost i obrazovanje—Agency for Science and Higher Education). The re-accreditation of a higher education institution is conducted every five years and evaluation of study programs is part of this process [24]. The above mentioned two acts are part of the modernization process of higher education and scientific performance. A

new requirement in the initial accreditation of a study programme is the opinion of the Croatian Employment Service on the compatibility of the new study programme with the labour market needs and the alignment with the standards of qualifications listed in the Croatian Registry of Qualifications [25]. The foundation of the new legal framework in higher education and science is provided by the National Recovery and Resilience Plan 2021–2026 of the Government of the Republic of Croatia [26], and in the main strategic document of the Republic of Croatia—the National Development Strategy of the Republic of Croatia until 2030 [27].

2.2. Czechia

The higher education system includes both public (26) and private (30) higher education institutions, mostly of university-type. The processes of curricula development are defined in the Act 111/1998 Coll. on higher education (amended and consolidated), and in the related regulations and methodical guidelines published by the National Accreditation Bureau for Higher Education [28]. This accreditation system defines national standards for all levels of study programs (i.e., undergraduate, graduate, and doctoral) in terms of their general scope and content, duration, assessment system, academic qualification of the teaching staff, research profile, and outcomes of the university in respective fields, and necessary research and educational infrastructure to conduct the study programme. While these requirements create frameworks for study programs, there is still some flexibility in which specific courses will be included in order to achieve the intended educational goals of the programme. In addition, some professions (such as engineering and planning) are regulated by sectoral governmental bodies, which also means that the study plan must be submitted for approval before obtaining accreditation from the Bureau. The study programs are accredited for a period of 5–10 years and each significant change to the programme profile and academic staff affecting educational goals, guarantees of the courses, and composition of basic compulsory courses is subject to reporting and approval.

2.3. Slovenia

Similar to Croatia and Czechia, higher education in Slovenia is organized in public universities (3), private universities (4 universities), and other higher education institutions (~40, including higher vocational colleges). NAKVIS (Nacionalna Agencija Republike Slovenije za kakovost v visokem šolstvu) and SQAA-Slovenian Quality Assurance Agency for Higher Education) are responsible for Slovenian higher education quality assurance (under the Higher Education Act). All study programs and higher education institutions should demonstrate their quality of education via the process of accreditation, which is led by the NAKVIS agency. NAKVIS differentiates among multiple types of accreditations (e.g., initial accreditation of higher education institution, accreditation of study programme, re-accreditation of higher education institution). The legislation related to the study programs accreditation is quite extensive, ranging from Higher Education Act and Higher Vocational Education Act to different regulations, such as criteria for the accreditation and external evaluation of higher education institutions and study programs [29].

3. Methodology

3.1. Curricula Analysis

Existing curricula at the university level in three countries (Croatia, Czechia, and Slovenia) were searched for courses that integrate NbSs with a focus on applications for water resources management. Higher education in all three countries is in accordance with a three-cycle study model of the Bologna system, which includes undergraduate, graduate, and postgraduate (doctoral) levels of study. This study was focused only on university profile study programs (excluding professional study programs usually performed at polytechnics and specialist university programs). Curricula at undergraduate, graduate, and doctoral levels were examined directly by authors, who also deal with NbSs and related

concepts in their research and teaching. All public universities were included in the search within the multi-phase methodology presented in Table 1.

Table 1. Methodological steps in the search for higher education curricula for NbSs-related approaches and techniques in water resources management across the three countries under study: Croatia (HR), Czechia (CZ), and Slovenia (SI).

	Methodological Step	Description
Step 1	Selection of NbSs-complementary concepts addressing water challenges on different scales (broadening the search)	Green-Blue Infrastructure (GBI) Green Infrastructure (GI) Natural Water Retention Measures (NWRM) Low Impact Design (LID) Sustainable Urban Drainage Systems (SUDS) Ecosystem Services (ES)—only if strictly related to water resource management
Step 2	Selection of keywords for country-specific curricula content analysis	HR: NbSs (rješenja temeljenja na prirodi), green (zeleno) rješenja, (solutions), water (voda), management (upravljanje), nature (priroda), environment (okoliš), ecology (ekologija), sustainable (održivo), flood (poplava), retention (zadržati/držati/retencija), land (zemljište), urban (urbana/gradska), blue (plavo), GI (zelena infrastruktura) CZ: NbSs (přírodě blízká opatření), GBI (zelená a modrá infrastruktura), sustainable urban drainage (nakládání se srážkovou vodou ve městech, hospodaření s dešťovou vodou, udržitelný městský odvodňovací systém), water retention (retence, zádrž vody), ecosystem functions and services (ekosystémové funkce a služby), river restoration (obnova/revitalizace vodních toků) SI: green (zelen), measure (ukrep) (nič), rešit (nič), water (voda), vode (nič), vodo, management (upravljanj), nature (narav), space (proctor), ecology (ekolog), sustainable (trajnost), change (sprememb), flood (poplav), okolj. Retention (zadrže), soil (tla), climate (podnebn), urban (urban), blue (modr)
Step 3	Detection of NbSs concept or specific techniques used for water resources management in curriculum	Examples of NbSs for water quantity and quality, applied on different spatial scales: • Stream revitalization, • Buffer strips for improving water quality, • Rain gardens, bioswales, etc.
Step 4		Frequency analysis of NbSs concepts or specific techniques for water resources management detected in curriculum

To increase the representativeness of the analysis and address regional and disciplinary traditions in the individual countries, we searched for concepts that are clearly related to the umbrella term of NbSs (Step 1). This is because some of these related concepts may be already present in curricula related to water resources. As a first step, widely used terms in the EU that fall under the NbSs umbrella were selected and added to the search: Green-Blue Infrastructure (GBI), Green Infrastructure (GI), Natural Water Retention Measures (NWRM), Low Impact Design (LID), Sustainable Urban Drainage Systems (SUDS), or Ecosystem Services (ES) if they were explicitly linked to water resources management.

For each country, preliminary keywords that best describe the selected concepts from the previous step were chosen, together with keywords corresponding to the water resources management for (Step 2). Since the use of different terminology and disciplinary discourses varies across the three countries, we selected more specific water resource man-

agement approaches and techniques related to NbSs. The spatial scale of these approaches and solutions varies from the river basin level at the large spatial scale to the sections of the watercourse in the medium spatial scale, and to a specific small spatial location (e.g., rain garden). This selection helped in the further addition of specific search terms (listed for each country in Table 1), where necessary, and in finding theoretical or practical parts of curricula that specifically mention these approaches and measures. The main requirement for including curricula in the list was that the selected NbSs concept or technique was explicitly mentioned in the course description, either in its annotation or syllabus.

The third step was to collect data on courses and conduct a content analysis of the identified courses for each country: University name, University size (approx. number of students), Research Field, Faculty name, Department name (if applicable), Study level (undergraduate, graduate, doctoral), Study program name, Course name, Start of the program (if available), Theoretical/Practical, Number of students (if available), Short description of the program, and Thematic keywords and specific NbSs approaches and techniques detected. Collected data are presented in Table S1 for Croatia, Table S2 for Czechia, and Table S3 for Slovenia. An analysis of the frequency of specific courses (Step 4) was conducted and a list of the most represented NbSs techniques for water quantity and water quality management is provided for each country. A schematic representation of the steps mentioned is shown in Figure 1.

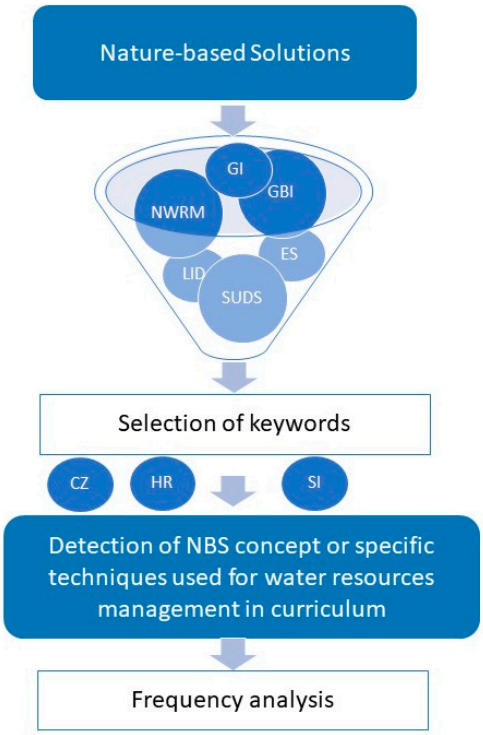


Figure 1. A schematic representation of the methodological steps in the search for higher education curricula for NbSs for water management in Croatia (HR), Czechia (CZ), and Slovenia (SI).

3.2. Bibliometric Analysis of the NbSs Research Papers

We performed a bibliometric analysis of research papers addressing NbSs in the three selected countries (i.e., Croatia, Czechia, Slovenia). A Scopus database search was conducted using the following search terms (i) TITLE-ABS-KEY (title, abstract, keywords): green AND infrastructure OR blue AND infrastructure OR urban AND drainage OR nature-based AND solutions OR natural AND water AND retention AND (ii) AFFILCOUNTRY (authors affiliations): Croatia OR Czechia OR Czech AND Republic OR Slovenia. The idea was to identify papers that focus on NbSs-related concepts and where authors were affiliated with organizations from Croatia, Czechia, and Slovenia. The search was per-

formed on the 16 October 2023. Freely available VOS Viewer software (version 1.6.13) was used for bibliometric analysis and research papers were imported in the software based on export of data directly from Scopus to .csv and .ris files [30–32]. Within the software citation, bibliographic coupling and co-citation analysis [30–32] of sources (i.e., journals) and topics were tested in order to identify publication patterns related to the NbSs concepts and authors from Croatia, Czechia, and Slovenia.

4. Results

4.1. NbSs-Related Concepts in Higher Education Curricula

4.1.1. Croatia

The curricula of public university study programs in the fields of natural sciences, engineering and technology, biotechnology, and social sciences (excluding humanities, arts, medicine, and biomedical sciences) that offer programs at undergraduate, graduate, and doctoral levels in the Republic of Croatia are examined, and the curricula of the courses were reviewed (if not available, the publicly available description of lectures was taken). The courses with lectures, exercises, and seminars on NbSs in water resources management were found at three out of eight public universities: the University of Zagreb, the University of Split, and the University of Rijeka (see Table S1). These universities are the three largest in Croatia in terms of the number of students enrolled in all study programs that they offer (between 16,483 and 64,306 students). A total of 18 courses were found in courses from agricultural sciences (11%, i.e., 2 courses), civil engineering (61%, 11 courses), forestry (7%, 3 courses), geography (6%, 1 course), and other environmental sciences (6%, 1 course). Although NbSs were not explicitly identified as a concept, the following NbSs-like concepts and approaches related to water were noted: GBI (5 courses), SUDS (8 courses), ecosystem services (3 courses), ecological water resource management (1 course), watercourse renaturalisation (4 courses), and vegetative buffer strips (3 courses). In general, the implementation of NbSs-related curricula in the identified courses is limited to a few lectures and exercises or is only evident from the course description. Most courses were taught at the graduate and doctoral levels, with slightly more than half being electives. The curricula provide mainly theoretical lectures together with practical work by the students (exercises, projects, or seminars).

Sustainable urban drainage systems and similar concepts (such as Best Management Practice, Water Sensitive Urban Design, and green and blue solutions for stormwater management) are widely addressed in courses in the civil engineering field at all three largest public universities. SUDS is introduced as an extension (one or a few lectures) to traditional curricula on urban drainage, focusing mainly on gray infrastructure. Additionally, watercourse renaturalisation and vegetative buffer strips are addressed as an extension to courses related to river engineering. A few curricula in the bioengineering field address NbSs as the following: (i) ecosystem services related to water and ecological aspects of water resources management in forestry field, and (ii) GBI in urban landscape design courses in agronomy field. In the natural sciences, there was one course in the biology department that covered aspects of GBI and ecosystem services related to water in its curriculum, and in the geography department, stream restoration was part of the curriculum.

4.1.2. Czechia

The analysis in Czechia was conducted for public universities since only they possess multidisciplinary curricula related to relevant study programs. Private higher education institutions are not university-type institutions and they mostly include only a couple of departments and focus on legal, management, engineering technology, art, and design studies, thus fields not relevant to the focus of our analysis. Of the 26 public universities, three only focus on arts and one on veterinary studies. Out of the remaining 22 public universities, the courses clearly dedicated to or explicitly including lectures and exercises on NbSs in water resources management were found at 10 public universities. Altogether, we identified 18 courses across engineering disciplines, environmental and social studies,

geography, and agronomical and forest sciences. Most courses are included in the curricula of geography (44%) and engineering sciences (28%). They combine both the theoretical and practical teaching modules (94%), and a slight majority is held in graduate study programs (56%). Half of the identified courses are facultative and semi-facultative, which—along with majority in higher levels of educations—indicate that NbSs remain an emerging concept that is not considered a fundamental to higher education curricula. Overall, the implementation of NbSs-related curricula is rather limited across all study programs and is basically represented either by few lectures and exercises in each course or is only indicated in course annotation. Thematic variability has shown certain patterns in relation to field of expertise, which can be described by three main clusters. First, NbSs related to river restoration and ecosystem services are most frequent in geography and related environmental study programs, followed by concepts of blue and green infrastructure, hazard-related catchment-scale water management, and sustainable urban drainage. Second, sustainable urban drainage (the term sustainable is frequently not explicitly included in lecture titles) is a concept related to natural science and engineering fields. In civil and environmental engineering, in particular, it can be considered an emerging concept that is used as an extension of conventional technical curricula oriented to designing gray infrastructure. Finally, ecosystem services are a concept implemented in social sciences, including social geography, and focusing on monetary analysis.

4.1.3. Slovenia

The review conducted in Slovenia considered the University of Ljubljana, the University of Maribor, and the University of Nova Gorica. The University of Ljubljana is the largest public university and provides 10 courses related to NbSs concepts (and water). No course related to the NbSs concept was found at the University of Maribor and the University of Nova Gorica (at least not directly addressing water-related issues). At these two institutions there were some courses dealing with sustainable development, ecosystem aspects, and general environmental topics, but no course dealing with water, NbSs, and related concepts. On the other hand, there was also quite a large number of courses at the University of Ljubljana dealing with sustainable development and general environmental aspects. However, these courses were not included in the detailed analysis because they were not primarily focused on NbSs-related concepts and water. Following the methodology described in Section 3, we identified 10 courses that were at least somewhat related to NbSs concepts and water. There is only one course that deals primarily with NbSs concepts and it is taught at the doctoral level. In other courses, other concepts such as blue-green infrastructure or green and blue infrastructure are mentioned. The scope of one course's hybrid infrastructure (including both gray infrastructures and NbS) is also specifically mentioned. Moreover, in Slovenia, most of the courses identified are in the fields of geography and civil engineering (i.e., over 70% in total), while in other fields only one course was included in this analysis (i.e., agronomy, forestry, and social sciences). In most cases, the courses are both theoretical and practical and only one course has only theoretical content. In addition, half of the courses are at the master's level and 30% are at the doctoral level. So, there is a tendency to cover NbSs-related topics at higher educational levels.

4.2. Bibliometric Analysis of the NbSs Scientific Papers—Wos/Scopus

Using the search term mentioned in Section 3.2 a total of 582 documents were identified. More than 300 documents were published in the Environmental Science field, followed by Social Sciences, Agricultural and Biological Sciences, Earth and Planetary Sciences, and Engineering fields with around 150, 130, 115 and 110 documents, respectively. Moreover, a clear increasing trend in the number of publications was detected based on the Scopus database. While before 2005 only a few documents per year (<20) were published on NbSs-related topics in the study countries, in recent years (after 2018) the number of documents is close to 80 per year. Most publications were published in English language while around 10 publications were published in native languages (Croatian, Slovenian, and Czech). In

terms of topics investigated, it was found that several publications are related to climate change, water management, and urban planning based on the conducted co-occurrence analysis of keywords (Figure 2). Co-occurrence shows the relatedness of items based on the number of documents in which they occur together. Additionally, it was noticed that research papers that were extracted from the Scopus database were published and cited in journals with impact factors like Urban Forestry and Urban Greening, Water Science and Technology, Sustainability, etc., but not really in top journals like Nature or Science. The focus of these research papers is on the environment, ecology, and sustainable aspects and less on the engineering applications. Hence, the bibliometric analysis revealed that only in recent years have authors from Croatia, Czechia, and Slovenia started to more frequently publish papers, book chapters, and conference proceedings related to the NbSs concepts.

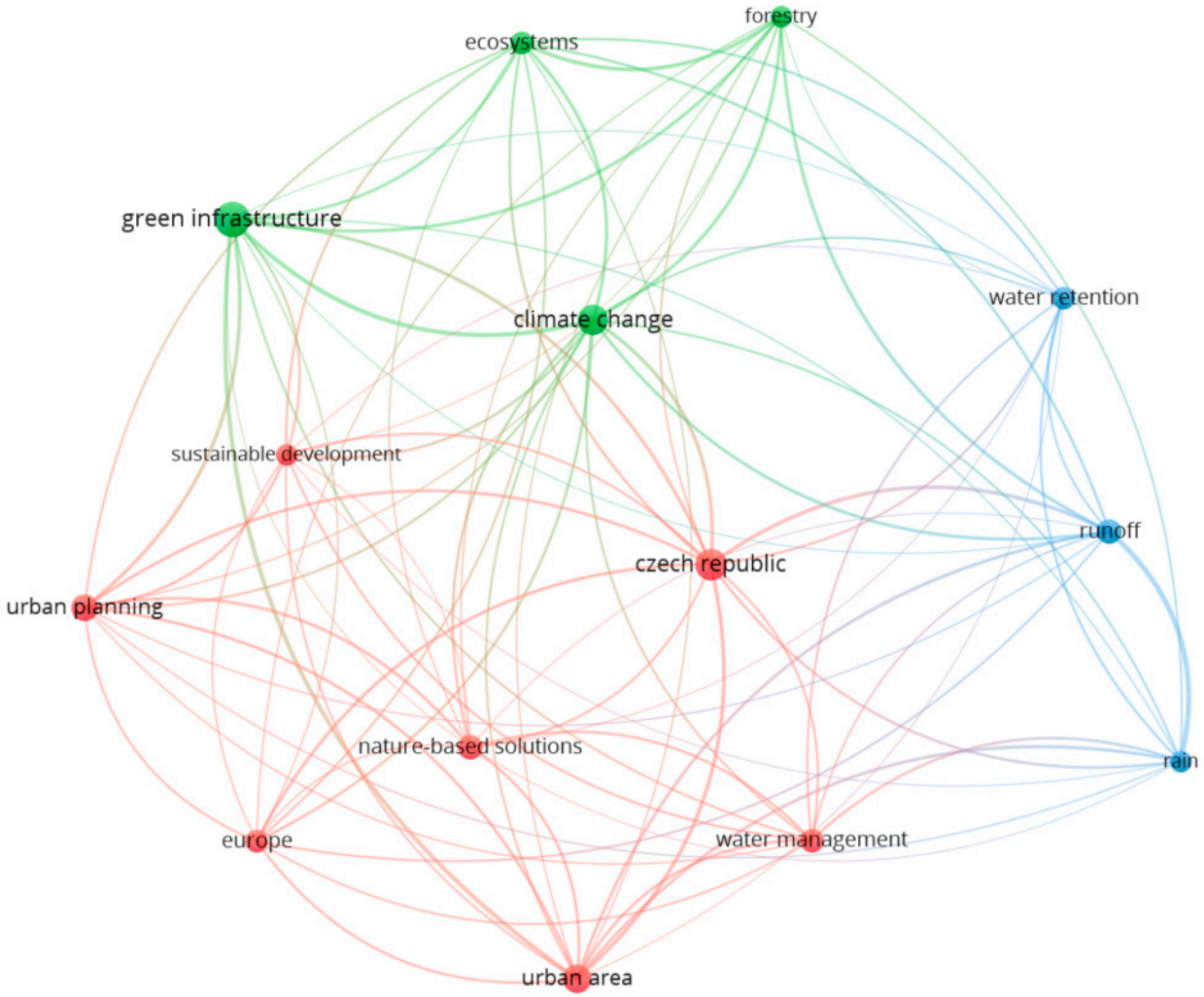


Figure 2. Co-occurrence analysis of keywords (related to documents) with a minimum of 29 occurrences of specific keyword (as shown in Figure 2). The size of the circle indicates the weight of the item, lines indicate connections among items, distance shows relatedness, and colours indicate clusters.

5. Discussion

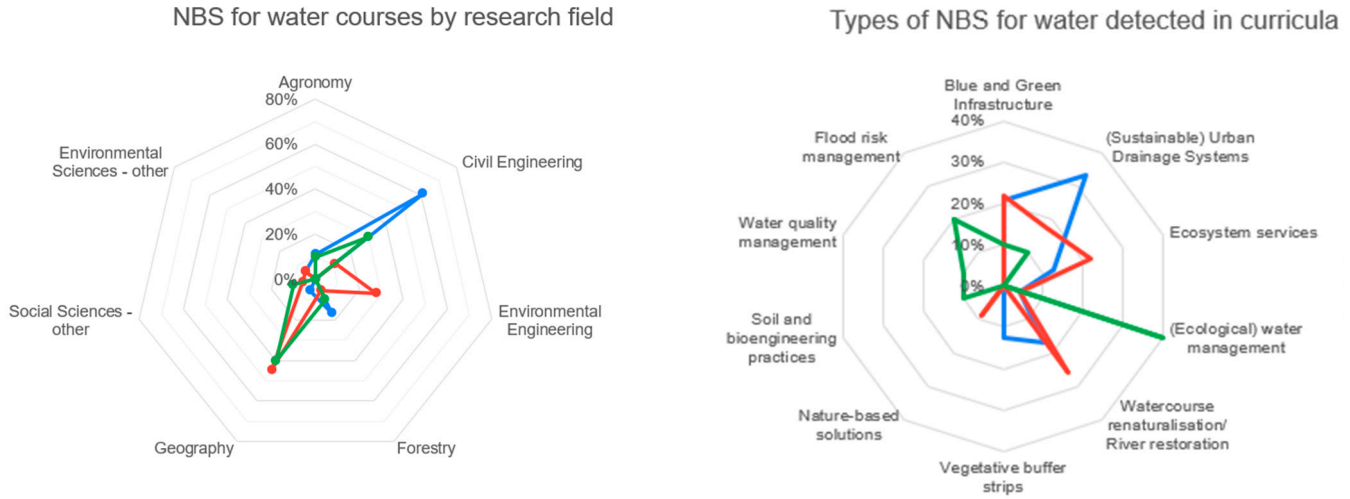
5.1. Integration Level of NbSs for Water in Study Programs—Comparison among Countries

Analysis of the curricula of public higher institutions in Croatia, Czechia, and Slovenia detected a total of forty-six courses (Table 2) that integrated NbSs for water resources management into study programs in six different research fields (Figure 3a). Overall, only two courses specifically dedicated to NbSs were detected in the three countries (in Czechia), while ten different approaches that may fall under the term NbSs were found in the various

study programs. The thematic variability in the detected approaches revealed certain patterns. First, sustainable urban drainage systems were present in the largest number of courses in Croatia (eight), Czechia (four), and Slovenia (one), mostly in the civil engineering field (Table 3, Figure 3b). Followed by blue and green Infrastructure, with five courses both in Croatia and Czechia and one in Slovenia; and ecological (environmental) water management, which was also found in all three countries (four in Slovenia, one in Croatia, and one in Czechia). Two additional thematic clusters were present only in Czechia and Croatia, related to the following: (a) River Restoration, with six courses in Czechia and four courses in Croatia; and (b) Ecosystem Services related to water management (five courses in Czechia and three in Croatia). In Slovenia, there was another relatively large cluster (but smaller than the ecological water management cluster) on flood risk management in general (not only SUDS) with two courses.

Table 2. Number of detected courses (and associated percentage values) with NbSs and NbS-like concepts (see Table 1) and techniques by research field in higher education curricula in Croatia, Czechia, and Slovenia.

Research Field	Croatia	Czechia	Slovenia
Agronomy	2 (11%)	0 (0%)	1 (10%)
Civil Engineering	11 (61%)	2 (11%)	3 (30%)
Environmental Engineering	0 (0%)	5 (28%)	0 (0%)
Forestry	3 (17%)	1 (6%)	1 (10%)
Geography	1 (6%)	8 (44%)	4 (40%)
Social Sciences—other	0 (0%)	1 (6%)	1 (10%)
Environmental Sciences—other	1 (6%)	1 (6%)	0 (0%)
SUM	18 (100%)	18 (100%)	10 (100%)



(**a**) (**b**)

Figure 3. Courses with integrated NbSs for water detected in higher education curricula in three countries in Europe: Croatia (blue), Czechia (red), and Slovenia (green), represented by: (**a**) percentage of courses by research field and (**b**) percentage of NbSs and NbS-like concepts and techniques related to water.

Table 3. NbSs and NbS-like concepts and techniques related to water in higher education curricula in Croatia, Czechia, and Slovenia.

NbSs and NbS-like Concepts	Croatia	Czechia	Slovenia
Blue and Green Infrastructure	5 (21%)	5 (22%)	1 (10%)
(Sustainable) Urban Drainage Systems	8 (33%)	4 (17%)	1 (10%)
Ecosystem services	3 (13%)	5 (22%)	-
(Ecological) water management	1 (4%)	1 (4%)	4 (40%)
Watercourse renaturalisation/ River restoration	4 (17%)	6 (26%)	0 (0%)
Vegetative buffer strips	3 (13%)	0 (0%)	0 (0%)
Nature-based solutions	0 (0%)	2 (9%)	0 (0%)
Soil and bioengineering practices	0 (0%)	0 (0%)	1 (10%)
Water quality management	0 (0%)	0 (0%)	1 (10%)
Flood risk management	0 (0%)	0 (0%)	2 (20%)
SUM	24 (100%)	23 (100%)	10 (100%)

The thematic variability in terms of field of expertise in study programs shows a strong clustering around civil engineering (16 courses) and geography (13 courses) in the three countries, followed by forestry (5 courses). Another cluster, present only in Czechia, concerns the environmental engineering field (a total of 5 courses, accounting for 34% of all courses identified). This clustering could be due to the fact that in Slovenia and Croatia, compared to the Czechia, NbSs are not integrated as a main approach in study programs in the field of environmental engineering. In Croatia, the largest and most pronounced cluster related to the integration of NbSs for water resources is slightly more pronounced in the field of civil engineering, which could be related to the fact that the curriculum is similar at all three of the largest universities in the field of civil engineering (Figure 3a). Although several courses related to water resources management were found in the agronomy and forestry field, no reference to specific NbSs could be found in the available course descriptions. Also, the distribution of courses in different fields and concepts used is most likely strongly influenced by the research focus of teachers who are responsible for the integration of new concepts into the higher education curricula as discussed in Section 5.2.

In general, more than 50% of all courses are integrated into high education level curricula in all three countries (Figure 4), providing both practical and theoretical foundations (with only one theoretical course in each country). The results show that only Czechia offers two courses specifically related to NbSs for water resources management, in addition to five different groups of NbS-like approaches integrated into ten higher education institutions in the three countries (Table 3, Tables S1–S3). This indicates that the overall integration of NbSs for water resources management into the Czech educational system is, both in terms of curriculum specificity and the variety of participating higher education institutions, surpassing Croatia (3) and Slovenia (1). In Croatia, the same number of courses as in Czechia was found (18), integrated in study programs spread over three different higher education institutions, and although the curriculum does not specify NbSs in any of the courses, it does contain six different groups of NbS-like approaches. The results for Slovenia show that all of the courses found in Slovenia were located at a single higher education institution, the University of Ljubljana (the largest university in the country) with four different groups of NbS-like approaches found, suggesting that this public university accumulates most of the knowledge on NbSs subject.

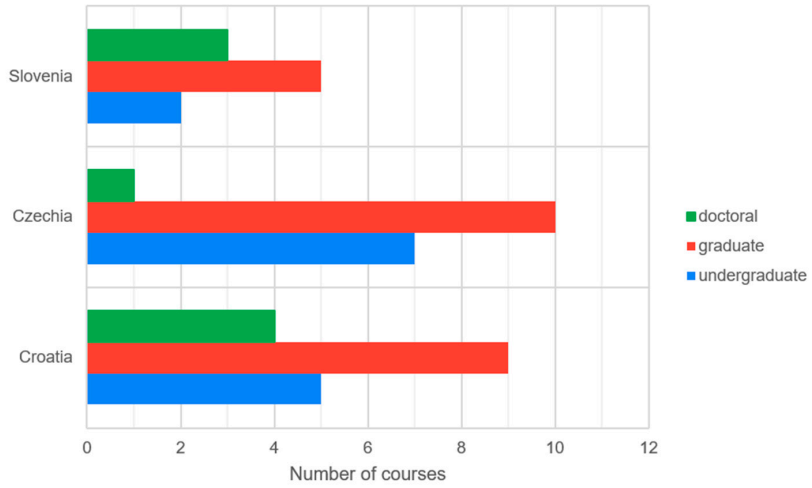


Figure 4. Number of detected courses with NbSs for water by study program level in Croatia, Czechia, and Slovenia.

5.2. Enhancing Understanding to Knowledge Translation in Higher Education

The majority of concepts related to the use of NbSs in water resource management have been gradually implemented in the courses and study programs of the European countries investigated. These concepts either represent additional components in accredited compulsory courses or are present in facultative and semi-facultative courses. Moreover, the concepts tend to be implemented in the highest levels of the education system (i.e., master and doctoral programs). In order to discuss and interpret the limited pace of implementation of these emergent concepts into the higher education curricula, we propose a typology of knowledge translation at the intersection of research and teaching practice. The typology is shown in Figure 5 and is based on the accreditation systems in the countries under study (see Section 2), the current literature, and results presented in Section 4.

The three pathways proposed in Figure 5 indicate the complexity and speed with which new knowledge is translated into the curricula. Firstly, direct incremental implementation through facultative courses or individual lessons is a pathway where researchers teach the course and implement his/her findings into the courses of existing accredited study programs. This finding can also be confirmed by the existing personal linkages between the research outcomes and the course identified in our study. As shown in Table 4, the NbS-like concepts related to water resources management are mostly taught by those who publish on the topic. This indicates that the respective concepts are still not widely implemented. Benefits of the first knowledge translation approach include fast knowledge translation and allow for avoidance of time-costs related to consensus building in multi-epistemic academic settings [20]. While such a pathway may present a viable option for validating the concepts in teaching practice, it also results in a fragmented nature in the emergent concepts across curricula, as was shown by our data where this type of knowledge translation pathway dominates.

Table 4. Research–teaching linkages between course lecturers and publication outcomes resulting from qualitative bibliographic analysis.

Country	Number of Courses	Share of Courses Thought by Authors of Papers
Croatia	18	67%
Slovenia	9	90%
Czechia	18	67%

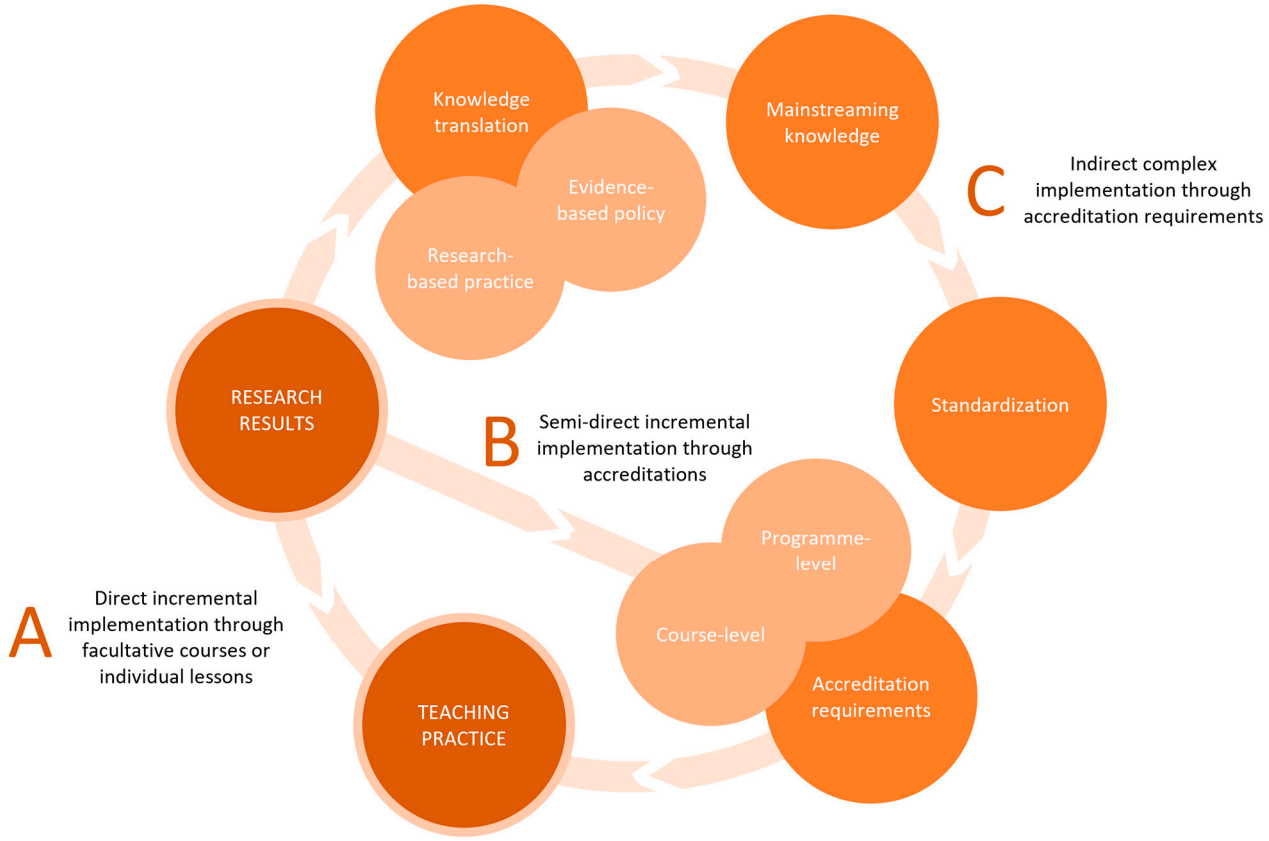


Figure 5. Typology of knowledge translation pathways at the research-teaching practice intersection.

Second, the semi-direct incremental implementation through accreditations is a pathway that requires consensus building in designing curricula at the universities; however, it may result in more comprehensive implementation of the emergent concepts. The concepts may be implemented either in compulsory courses or in whole study programs, but their extent remains limited across and within the higher education institutions. Both the direct and semi-direct incremental implementation pathways may also contribute to the complex implementation described in the indirect implementation pathway below.

Third, the indirect complex implementation through accreditation requirements is the most comprehensive, but also indicates a gradual pathway that has not been identified in the countries under study so far. The process fundamentally relies on closing the research–practice gap, where mainstreaming and standardization of emergent concepts contribute to a coherence within the triple helix [17]. However, reaching such coherence is never simple due to differential pace and feedback among the research, industry, and government sectors, thus creating different expectations and new tensions among them [18]. Higher education institutions may provide a relevant contribution to such coherence through incremental implementation of emergent knowledge (direct and semi-direct types) and by negotiating applied research funding schemes with industry and government sectors. At a certain point, a viable level of coherence is achieved and the knowledge becomes sufficiently embedded in a professional practice (e.g., planning documents, public discussions on land instruments, and interventions) and policy (e.g., strategic documents, public funding schemes). Finally, such a knowledge domain is included in the accreditation requirements and any new study programs are expected to implement such knowledge (concepts and approaches) to be approved by accreditation authorities. Even within the indirect type, the process may be more variegated since it depends on whether governmental bodies and professional associations have the authority to co-define the requirements for accreditations. The presence of such power entities may either speed-up or hinder knowledge translation [16].

Given the pressing challenges of current environmental change and its impacts [1–3], the essential question could arise of what the most effective and efficient pathway for knowledge translation is, and what or who are the enablers of such translation. In this respect we should emphasize that similarly to a varying relevance of knowledge translation barriers across the countries, the leverages, and enablers would also vary. Therefore, defining a one-size leverage for all would be tricky and, along with assessing the success of knowledge translation by the overall numbers of courses, a detailed insight into the variances across the disciplines is needed. We see two main opportunities to enhance knowledge translation within the disciplines. First, supporting a symmetric approach to co-creation of the curricula by academia and professional associations may support bridging the research–educational policy gaps. Second, we call for stronger engagement in researchers–educators in defining the accreditation policy processes. This may go beyond defining the qualification requirements for accreditation and could focus more on the competencies graduates should obtain during and after their studies within the life-long learning programs [33,34].

5.3. Limitations of the Study

The present study has multiple methodological limitations that affect the completeness of the list of identified courses. First, the accessibility to information on courses differs considerably across the countries and the universities and some courses therefore might have not been identified using the key words in web search. In some countries with a high number of universities, such as the USA, artificial intelligence methods could be used to extract the information about courses less subjectively. Second, the description of courses (annotation and syllabus) does not have a strict form and is usually written by the educators. Therefore, even if some topics are being taught in the respective study programs, the disciplinary and epistemic terminology may proliferate into the descriptions and affect the results. Hence, this can impact some of the derived classifications as for example the one shown in Figure 3. We attempted to minimize this bias by selecting the terminology present in the individual country contexts. On the other hand, while doing so, the authors' professional background may have influenced the selection of key words as it varies from environmental geography to pure hydrology. In combination with the limited number of courses related to the NbSs concepts and water resources management in Croatia, Czechia, and Slovenia, this could potentially indicate some uncertainty in the derived results. Taking into account these limitations, the authors did a repeated check of the courses in the countries and also discussed the eventual impact of variations in the methodological approach on the consistency of the results. While we do not claim that the study provides a complete list of courses in the respective countries, it does present a representative sample of courses (provided by the public universities in each of the three countries) that allowed for us to identify patterns in dominant approaches and techniques and conclude on prevailing methods of knowledge translation in higher education curricula. The study could be extended to other countries with a larger number of NbSs courses where the results would be more robust. Alternatively, interviews could be used to gain more in-depth understanding about the knowledge transfer from research to teaching. Finally, the findings presented in this study are limited to three specific countries. While this was a pragmatic choice to ensure the feasibility of the research and validation of the methodology, the study should be expanded to the European scale since other countries may have more dedicated courses and programs compared to the selected countries. However, the direct examination of curricula conducted by the authors at undergraduate, graduate, and doctoral levels can also be considered a limitation per se, as its replication to countries with a large number of universities would be extremely time consuming and could be considered unrealistic. Furthermore, the methodology used requires easily available information about curricula in different universities. Although this was found in the three countries investigated, this may not be the case in other countries. An alternative methodology to assure the access to data could be through direct contact with

the accreditation institutions and access to the curricula of higher educational programs. Then, available methodologies to search for keywords in multiple documents of different extensions (e.g., txt, pdf) without opening them (e.g., AnyTXT Searcher) could be used to hasten the search of relevant curricula.

6. Conclusions

Nature-based solutions (NbS) have been recently promoted as viable approaches and measures that complement engineering solutions when addressing the impacts of climate change. In this paper, we argue that their broader implementation must be based on wide and effective implementation in the higher education curricula. Adopting a concept of knowledge translation, the integration of NbSs for water management into undergraduate, graduate, and doctoral curricula in Croatia, Czechia, and Slovenia was conducted in this study. Several issues were detected related to the translation of NbSs to study programs. Firstly, our results indicate that integration of NbSs into curricula is currently limited to 2 courses in Czechia addressing water resources management (from the total of 46 courses detected in all three countries) which are taught mostly at highest education levels (master and doctoral). Most courses cover concepts (10 detected) that fall under the umbrella of NbSs where the largest groups found in all three countries are related to sustainable urban drainage systems, blue-green infrastructure, and ecosystem services. The thematic variability in terms of field of expertise in study programs showed a strong clustering around civil engineering (16 courses), and geography (13 courses), followed by forestry (5 courses). NbSs and these concepts are integrated as a limited part of accredited compulsory courses and/or are offered in facultative and semi-facultative courses. Secondly, the extent and descriptions of the identified courses along with the analysis of authorship co-occurrence of publications from guarantors and lecturers of the courses indicate that direct incremental NbSs knowledge translation is a predominant pathway in the three countries. Research–teaching linkages between course lecturers, and publication outcomes resulting from qualitative bibliographic analysis, showed that the proportion of courses taught by the authors of publications on the subject was 67–90%. This means that knowledge translation is based on the individual preferences of educators rather than a mainstream agenda for the accreditation of study programs. These results are in strong contrast with the pressing challenges of climate change and also with general claims and goals made by international organizations. For example, education is identified in the EU Growth Strategy and the EU Roadmap to a Low Carbon Economy as one of the cornerstones to achieving higher levels of citizen participation and engagement. Other concepts also support these efforts [35–38].

To strengthen the integration of NbSs for water resource management in study programs, and to accelerate the integration process, the transfer of knowledge and best practices from countries and universities with the highest levels of implementation to countries and universities with lower levels of implementation of NbSs for water in high education study programs is needed. The specific opportunities for leveraging knowledge translation can be supported by professional associations bridging academia, policy, and practice in water resources management. Furthermore, we assert that instead of too much focus on qualifications and formal requirements in the higher education accreditations, emphasis should be paid to the professional competencies of graduates and to life-long learning over their career paths. The main limitations of the study are related to the small sample of countries in our study and the possible subjectivity due to the professional background of the authors. Therefore, we suggest that further research and comparisons of existing curricula with additional interviews on the European level are needed to provide more robust results, together with an exploration of pathways to transfer up-to-date knowledge from completed and ongoing research projects on NbSs for water management (e.g., [39–42]) into curricula. Additionally, we argue that these findings highlight the need to update and refresh existing curricula and introduce new study programs with NbSs as an approach to

address current environmental, climate, and societal challenges, as already recognized in EU legislation.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land12112050/s1, Table S1: Detected courses with NbSs and NbS-like concepts and techniques in higher education curricula in Croatia (HR). Table S2. Detected courses with NbSs and NbS-like concepts and techniques in higher education curricula in Czechia (CZ). Table S3. Detected courses with NbSs and NbS-like concepts and techniques in higher education curricula in Slovenia (SI).

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Data Availability Statement: The data presented in this study are available in this article and in supplementary material: Tables S1–S3.

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