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Report on the third Space4Water stakeholder meeting

(Vienna 24 and 25 October 2023)

I. Introduction

1. The Office for Outer Space Affairs and the Prince Sultan Bin Abdulaziz International Prize for Water organized the third Space4Water stakeholder meeting, which was held in Vienna on 24 and 25 October 2023 in a hybrid format.

2. The present report describes the objectives of the meeting and includes details of attendance and a summary of the presentations, discussions and interactive sessions, as well as the conclusions.

II. Background and objectives

3. The Space4Water project and its dedicated Space4Water portal were launched in 2018 under a memorandum of understanding with the Prince Sultan Bin Abdulaziz International Prize for Water. Since 2021, the scope of the agreement has included new areas of cooperation, including community-building activities. A community of practice consisting of stakeholders, professionals, young professionals and members of Indigenous communities ("Indigenous voices") has been established over the past years of the project and through Space4Water stakeholder meetings organized since 2022, to foster the in-person exchange of knowledge and the co-design of space-based solutions to address water-related challenges.

4. The programme of the third Space4Water stakeholder meeting included technical presentations selected through a call for abstracts, a panel discussion on multi-stakeholder engagement and informed decision-making, interactive sessions on community objectives and community-building, and hands-on sessions focused on the development of co-designed draft solutions outlining the steps to be taken to address previously identified water-related challenges.

5. The meeting was an opportunity for stakeholders to exchange views and put forward suggestions for a better understanding of the diverse nature of water-related challenges faced by communities globally.

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III. Attendance

6. Of the 60 individuals who registered for the meeting, 15 (25 per cent) were women. Of the 28 individuals who participated in the meeting, 35 per cent were women.

7. Individuals from the following 21 countries participated in the meeting: Argentina, Austria, Brazil, Bulgaria, Costa Rica, Democratic Republic of the Congo, Egypt, Ethiopia, Ghana, Guatemala, India, Italy, Kenya, Mexico, Morocco, Nepal, New Zealand, Pakistan, South Africa, Sri Lanka and Sweden.

8. Online attendance fluctuated depending on the time zones that the online participants were in. Six participants took part in the meeting online.

9. Participants were invited to use the online platform to pose written questions using the chat box during discussions, and the organizers used the same interface to provide complementary information.

IV. Programme

A. Overview

10. The programme comprised presentation sessions, panel and round-table discussions, presentations of lightning talks and hands-on sessions in which space-based solutions were co-created.

11. The display of posters, intended as the online equivalent of an in-person poster session, increased the number of initiatives and research projects presented.

12. The total duration of the event was about 16 hours over the course of two days. Presentations were delivered by 24 speakers, of whom 10 were women and 14 were men. The programme comprised 10 sessions, including an opening session, a session dedicated to the introduction of participants and three sessions featuring technical presentations: on space technologies and water security, space technologies and water quality assessment, and data, systems, software and tools for water resource management and hydrology. Interactive sessions held during the meeting included a session on the Space4Water community, a session involving two keynote presentations followed by a panel discussion on multi-stakeholder engagement, communities and informed decision-making. Finally, a hands-on session in which participants co-created space-based solutions for previously identified water-related challenges was conducted, and presentations on the draft solutions were delivered.

13. All of the presentations delivered during the meeting are available on the dedicated web page of the meeting on the Space4Water portal,[1] on the individual profile pages of speakers, which can be found under the “Stakeholders”, “Young professionals” and “Indigenous voices” tabs of the “Community” section.

B. Opening of the meeting

14. The third Space4Water stakeholder meeting was formally opened by the Director of the Office for Outer Space Affairs by means of a pre-recorded opening speech, in which she highlighted the ongoing global water crisis, initiatives undertaken by the international community such as the 2030 Agenda for Sustainable Development and Sustainable Development Goal 6, Global Acceleration Framework, and the need for action and collaboration to address water-related issues globally. She also highlighted the interconnectedness of water and many aspects of life on Earth and thus the need to address water-related issues. Laying out the potential of space technologies to do so, the Director emphasized that a divide in the space sector must

[1] Available at www.space4water.org/news/third-space4water-stakeholder-meeting.html.

be avoided. There was a need for capacity-building, and the Office would pursue activities to fulfil its mandate related to sustainable development, reinforcing capacities for the use of space technology to address water-related issues.

15. The Director of the Prince Sultan Bin Abdulaziz International Prize for Water delivered opening remarks. He noted that the Prize had been established in 2002 and consisted of four specialized prizes covering the entire water research landscape that were awarded every two years. Nominations for the eleventh award were open until 31 December 2023. The Director acknowledged the long-standing relationship with the Office which dated back to the first International Conference on the Use of Space Technology for Water Management, held in 2008, as well as the Office’s work in implementing the Space4Water project. A memorandum of understanding establishing the cooperation on the Space4Water portal and project had been signed in 2016 and renewed in 2021.

16. Lastly, a representative of the Office delivered a presentation providing an overview of the Space4Water project and its three pillars: the conference series, the portal and community-building. It was noted that since the beginning of the conference series in 2008, the project had brought together more than 600 people from more than 140 countries through the five conferences held. Launched in 2018, the Space4Water portal was continuously being developed. The representative of the Office shared statistics on the portal’s content and users.

17. The Space4Water community, as of October 2023, comprised 97 stakeholders, 17 professionals, 27 young professionals and 7 representatives of Indigenous communities (“Indigenous voices”). It was highlighted that the focus was no longer on increasing the community but on the quality of exchanges to address pending issues in order to provide good service in protecting water on Earth in all its forms. The need to now focus on capacity-building was highlighted. The objectives of the meeting were as follows:

(a) To foster the exchange of knowledge between Space4Water stakeholders, professionals, young professionals and members of Indigenous communities;

(b) To co-develop space-based solutions for water-related challenges;

(c) To identify and address other ways to improve interaction among the Space4Water community and to achieve shared objectives.

18. It was announced that the next edition of the International Conference on Space Technology for Water Management would be held in 2024.[2]

C. Introduction of participants

19. All participants had an opportunity to introduce themselves, or the stakeholder they represented, and were invited to share information on the thematic and regional focus of their work, as well as whether their work concerned the local, national, regional or international level.

D. Technical presentations: space technologies and water security

20. A representative of the Space and Upper Atmosphere Research Commission (SUPARCO) of Pakistan, a government stakeholder, delivered a presentation on water resources mapping and monitoring using remote sensing and geographic information system technologies. The representative emphasized that geospatial technologies must be considered because they were crucial for the analysis of water resources on the spatial and temporal scales. He noted that the use of such technologies for analysis

[2] At the time of writing of the present report, it had been agreed that the Government of Costa Rica would host the conference at the headquarters of the Inter-American Institute for Cooperation on Agriculture, in San José, from 7 to 10 May 2024.

was essential for combating multidimensional societal challenges and orienting humanitarian and development-related actions. Among the development challenges he mentioned in relation to water resources were population growth, migration to urban centres, the non-efficient use of water, the lack of innovation, the lack of protection of groundwater, climate change and the lack of access to information. He stated that food, water and energy could not be considered separately and that Earth observation and remote sensing were the solution to answer the essential questions of when, where, who and how with regard to water-related challenges. Lastly, solutions and successful tools developed by SUPARCO were presented, including the following:

(a) A geographic information system-based land acquisition database for the monitoring of dams and determining their feasibility in the Province of Balochistan, Pakistan;

(b) The identification of potential agricultural lands;

(c) A digital inventory of the irrigation network in Pakistan;

(d) An inventory of glaciers in Pakistan using very high-resolution data (up to 1 to 2 metres), with an example of the Shisper glacier (involving a time-series analysis showing the impact of climate change, which was used to inform and protect local populations);

(e) The development of a national catastrophic modelling tool in the form of a database and web application for the assessment of hydrometeorological hazards;

(f) Flood hazard maps: probability mapping for the better targeting of humanitarian action;

(g) The assessment of the cotton crop in Sindh Province during the flood of 2022;

(h) Monitoring of the sea level.

21. A representative of the Kenya Space Agency delivered a technical presentation on the use of spatial analysis to address water scarcity in arid and semi-arid areas. The speaker highlighted the need for water scarcity maps and the difficulty of accessing clean water in arid and semi-arid areas in Kenya, where women and children often had to travel long distances to obtain water. The case of Wajir county, where pronounced aridity was creating difficult conditions for livestock and livelihoods, was presented as an example. It was highlighted that, because of the seasonality of rivers in the region, boreholes along the riverbanks were the most reliable water sources. The national Government, the county government and non-governmental organizations were supporting communities' efforts to drill more boreholes. The Kenya Space Agency and the county government were currently looking for additional partners to replicate the project in other arid and semi-arid areas.

22. The representative of Chouaib Doukkali University in Morocco and the African Association of Remote Sensing of the Environment delivered a presentation on spatial exploration for monitoring water stress: towards a new paradigm for the optimal management of irrigation water in the arid Doukkala region in western Morocco. The speaker noted that Doukkala was a very important area for crop production in the country. He reported on the increased imbalance between water use and water availability and the negative feedback loops related to population growth, touristic development and industrialization, which had led to the extension of irrigation areas and observed effects of climate change and had put even greater pressure on water resources. Projects such as AFRI-SMART[3] and "Crop stress monitoring in the semi-arid context of Doukkala" ("CrosMoD"), funded by the African Framework for Research Innovation, Communities and Applications in Earth Observation ("EO Africa") of the European Space Agency, provided short-term irrigation forecasts for

[3] Available at www.afrismart.polimi.it/#description.

better planning based on the calculation of crop water demand; those forecasts were prepared three times per year: at the initial stage, mid-season and at the development stage. A new crop water demand map was produced every week. The speaker explained that crop water productivity[4] maps aided understanding of the significant differences in the productivity of the same plot of land, which were mainly due to differences in plot management. The presented model[5] was designed to produce strategic plans for irrigation.

23. A presentation on modelling the impacts of climate change and land use and land cover dynamics on ecosystem services: a case study of the Pindar River watershed in the Indian Himalayan region was delivered by a representative of the Govind Ballabh Pant University of Agriculture and Technology, India. The speaker noted that the Himalayas provided water to at least 1.3 billion people and were considered the "water tower" of India. The Pindar River watershed had been delineated in the study using, inter alia, precipitation and evapotranspiration data to develop a tool that was used for policy- and decision-making.

24. A presentation entitled "Space-based thermal infrared intelligence for ex-peatland identification" was delivered by a representative from the stakeholder Constellr. The speaker noted that peatlands were crucial for climate, biodiversity, flood control and water retention. They were also the largest natural carbon store. Burning and mining had contributed to massive degradation of peatlands. Their restoration was crucial at the international level. As a priority under the European Green Deal and as a measure against the effects of climate change, an assessment of former peatlands that had been converted into fields had been carried out by the stakeholder. The speaker highlighted that the initiative further restored lands that had sometimes been taken from Indigenous people.

25. A presentation on the sustainable management of the ancient Yoda Ela by applying nature-based solutions was delivered by a Space4Water professional from the University of Texas at Arlington, United States of America. The over 2,500-year-old complex irrigation system in Sri Lanka included canals, tanks, reservoirs and tank cascades and had provided a continuous water supply to communities in the dry zone of the country, where water scarcity is a major issue. Climate change has a great impact on the system. The giant canal (Yoda Ela) dated to the fifth century A.D. After the Tissa Wewa reservoir, which supplied water to the city centre, dried up, both it and several other reservoirs in the watershed have been consistently receiving water from the Kala Wewa reservoir. That has been facilitated by an 87 km-long water canal with a low gradient and single banking. It had been built along a similar contour line of 300 m and was a moving reservoir owing to the relatively slow water movement, which allows groundwater recharge and ecological sustainability. The canal's meanders allow water to be retained and purified. The New Gaga canal had impacted Yoda Ela, as it is not based on the same sustainable technology used for the Yoda Ela. The assessment described in the presentation was based on Earth observation data, and geographic information system-based analysis has been conducted in the area to identify changes over time. Examples of the space-based data and indices used include a digital elevation model and the normalized difference vegetation index.

E. Technical presentations: space technologies and water quality assessment

26. The stakeholder Remote Sensing, and Climate Research Lab of the University of Punjab, Pakistan, presented on space-based observations for water quality

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[4] Crop water productivity is the ratio between water consumption and crop growth.

[5] The FEST-EWB_SAFY model is a coupled model based on a parameter-saving crop growth model (Simple Algorithm For Yield estimates (SAFY)), with a water-energy balance model (Flash-flood Event-based Spatially-distributed rainfall-runoff Transformation – Energy Water Balance model (FEST-EWB), which is a water-energy balance model.

assessment. In the research presented, a dammed reservoir was monitored using multi-temporal and multi-spatial images from a multispectral instrument (MSI on Sentinel-2) as well as monthly rainfall data from a meteorological station. The speaker highlighted that water needed to be monitored in the context of climate change. Underdeveloped countries were suffering greatly from a lack of financial resources – a challenge for conducting proper scientific studies and which led to projects being implemented without a scientific basis. A case study on the rain-fed Khanpur reservoir of Pakistan was presented, for which a key concern was water quality because water was used both in homes and by industry. Indicators to estimate water clarity included “total suspended matter” (TSM) and Secchi disk depth (SDD), which were calculated using both a qualitative and a quantitative method. The case study illustrated how satellite images can be a cheap and easy substitute for ground measurements, especially for developing and least developed countries. The results showed that the months of January, July and September were characterized by the high turbidity and poor trophic state (SDD < 1 meter) of the reservoir water as per preliminary estimations of Secchi disk depth and TSM retrievals from the Case 2 Regional CoastColour (C2RCC) analytical neural network model.

27. A study analysing water quality of the Phewa and Begnas lakes using Sentinel-2A data and the collection of in situ data samples from the lakes was presented by a representative from the Center for Space Science and Geomatics Studies at Tribhuvan University, Nepal. Deteriorating lake surface water quality could be attributed to pollutants from human activities. The lakes had a high impact on the economy of Nepal. The water quality parameters for both lakes that were analysed included carbon, total suspended solids and turbidity.

28. The study entitled “Spatiotemporal variability of the Tana Lake water quality derived from the MODIS-based Forel-Ule Index: the roles of hydrometeorological and surface processes” was presented by a young professional from Wollo University, Ethiopia. The method used was Forel-Ule Index colour comparator scale consisting of 21 colours. The Forel-Ule Index scale has recently been applied to remote sensing data. The natural colour of water has been measured globally since the nineteenth century. That monitored in situ information has been successfully combined with remote sensing data from the lake. The study used data from Moderate Resolution Imaging Spectroradiometer (MODIS) and Medium Resolution Imaging Spectrometer (MERIS) satellites, as well as drought and Standardized Precipitation Evapotranspiration Index (SPEI) data. Variables such as wind speed and ambient temperatures affect the quality of the water. Wind speed positively correlates with turbulence, which decreases the water quality. Similarly, a rise in ambient temperatures leads to a decrease in water quality. Hence, water quality changes over the seasons. To conclude, the optical property of inland water bodies is typically complex and variable. The Forel-Ule Index is a feasible method for evaluating the quality of inland water bodies in large regions for long time periods.

29. Another study presented by a Space4Water professional from the Wolkite University of Ethiopia assessed seasonal dynamics of suspended matter and chlorophyll a concentration in the Ziway and Hawassa lakes of the Rift Valley lakes basin in Ethiopia using Sentinel-3A data, demonstrating that these lakes are impacted by sedimentation, point and non-point sources of pollution and a large increase of chlorophyll a. The primary stakeholders impacted are farmers, fishers and inhabitants of Ziway and Hawassa, and prompt action in the form of monitoring is key. A comprehensive analysis, complementing the many existing baseline assessments, assesses total suspended matter, chlorophyll a concentration, turbidity, water surface temperature and Trophic State Index using remote sensing. The chlorophyll a time-series shows spatial and temporal and seasonal fluctuations. Point and non-point sources of pollution from nearby cities may be the main cause of changes. Riparian buffer zones with vegetation and grasses are highly recommended to counter the pollution. This preliminary study will be validated by the statistical institute. More partners are needed to improve the research.

30. A Space4Water professional from the German University in Cairo presented the effect of global warming on dissolved oxygen concentrations in the Nile River, supported by data from the INSAT-3D meteorological satellite of India, as well as from Sentinel-2A and Sentinel-2B. The aim of the study was to predict the critical dissolved oxygen concentration values in the Nile River. River waste load allocation was calculated for waste locations, degraded areas and regenerated areas, where the river is clean again, and needs to be kept clean. Dissolved oxygen is one of the major parameters used to assess water quality for human use. Water temperature and dissolved oxygen were calculated at two stations (Luxor upstream and Alexandria downstream). It was highlighted that studies on global warming and dissolved oxygen need to be carried out to design river waste load allocation.

F. Technical presentations: data, systems, software and tools for water resource management and hydrology

31. The stakeholder National Water and Sanitation Agency (ANA) of Brazil presented the Atlas study hydrographic data set (BHAE), an approach to the homogenization of multiscale databases. Use of a hydrographic dataset incorporating the Pfafstetter coding system led to the Atlas study hydrographic data set. The main advantages of this coding system are the use of natural and hierarchical variables. This coding system makes it possible to automatically calculate the location of upstream and downstream areas within the geographic information system. Furthermore, the original data set was transformed into 400,000 drainage lines. Advantages of that data set are fast processing in geographic information system desktop software and the fact that no geometric bias is caused by different scale mappings.

32. "Introducing EOdal: an open-source software for Earth observation data analysis" was presented by an Austrian Space4Water young professional from the Swiss Federal Institute of Technology of Zürich. The goal of this project is to develop an open-source digital twin related to crops to democratize access to actionable insights for agriculture, enable efficient information transfer and connect actors in agriculture. It will use crop models and satellite imagery. The software shall reduce the high barrier in using open-source libraries and frameworks, enabling everyone to use Earth observation workflows by using tools to analyse data. Functionality includes, for example, combining series of images of Sentinel-2 to monitor floods and assess their impacts. A call was made for contributions from experts, whether related to coding or not.

33. Forecasting discharge and water levels of rivers and dams using Earth observation and artificial intelligence was presented by the stakeholder Mozaika of Bulgaria. The project has been supported by funds from the European Space Agency. Exploitation of rivers and reservoirs involves daily monitoring of water resources, meteorological conditions, status of riverbanks and flood areas. The forecast method is based on satellite data, geospatial positioning and in situ measurements such as of discharge, water level and turbidity. Gaps in satellite data, for example, owing to, but not limited to, cloud cover, are filled with generative machine learning algorithms. Resulting forecasting models show overall good results compared with official data. The forecast also includes an alert system.

34. The risk exposition indicator for irrigation user associations, a space-based tool for risk management of rural communities' water resources, was presented by the stakeholder Inter-American Institute for Collaboration on Agriculture of Costa Rica. Within the project, a risk exposition index for natural and anthropogenic events has been developed to make complex data simple and accessible. Data sources include shapefile and raster data. The product delivered to communities is a dashboard focusing on different risk exposures for each area. The speaker highlighted the important role of maps which can be seen as a universal language that everyone can understand and hence are a powerful tool to foster understanding at the level of local communities without technical background.

G. The Space4Water community

35. The session on the Space4Water community allowed each participant to take the floor and share information on projects, methods or tools that the community could benefit from. It covered a wide range of topics related to remote sensing, environmental monitoring and the utilization of space technologies for various applications and research efforts.

36. The use of remote sensing and environmental monitoring included topics such as aquifer level changes and groundwater vulnerability assessments, as well as climate change and hydroclimatic modelling. Several speakers discussed data-sharing and underlying infrastructure such as open-source data sets, infrastructure frameworks, the use of the Google Earth Engine for time series analysis, and the importance of sharing water resource information with stakeholders at different levels. A few speakers emphasized community engagement and education and how space technologies can be brought to rural communities, teaching and engaging students in remote sensing, as well as providing tools and code for the community. Flagship satellite missions, efforts to estimate crops using remote sensing and models that help policymakers to assess the effects of climate change effects and prioritize problems were also mentioned. Speakers mentioned innovative research and optimization, the covering of irrigation canals with solar cells in order to preserve water quality, and the use of space technologies to study rapid land use changes. Models for hydroclimatic data, disaster management and initiatives to map small-scale agriculture and farming were also mentioned, as well as the need to fund such initiatives. Finally, a few speakers mentioned international collaboration and scholarships, in particular in the context of supporting young Africans who want to study or share projects using remote sensing.

H. Multi-stakeholder engagement, communities and informed decision-making

37. The representative of the University of Energy and Natural Resources of Sunyani, Ghana, presented the conflicting needs of mining and cocoa production in Ghana. In Ghana, mining was one of the most important economic sectors, providing employment to many people. It was also a very complex industry with a lot of actors. Unregulated mining had disastrous consequences and was attracting young people lacking alternative livelihoods. Rivers had become increasingly polluted within the past 10–15 years. Following the coronavirus disease (COVID-19) pandemic, the price of cocoa in Ghana fell compared with the price of gold. Consequently, farmers tended to sell their lands to miners, a phenomenon contributing to land and water quality degradation. Earth observation must be used to monitor those problems and it was demonstrated how platforms are used to provide analysis-ready data to assess the situation.

38. A presentation on groundwater was delivered by a member of an Indigenous community and Space4Water professional from Mexico. There was a presentation and discussion on a toolbox that had been developed with more than 600 stakeholders on the basis of a literature review and stakeholder knowledge and integrating local communities' knowledge in decision-making processes related to groundwater. The toolbox reflected the results of a system analysis, as well as work in groups to develop scenarios involving drivers and risks, biocultural approaches and underwater and cave explorations. It also led to the clean-up of cenotes (aquifers) and helped to restore community values. The application of the models and the toolbox in different places and regions was considered by participants, as well as its inclusion in the Space4Water portal.

39. The discussion addressed effective decision-making regarding groundwater issues and the importance of increasing groundwater literacy among stakeholders. The role of Earth observation and geospatial technology in supporting

informed decision-making and water governance, as well as the challenges of capacity-building, were discussed. Brazil was seen as a positive example because its governmental agencies used remote sensing data for decision-making related to water resources.

40. Additionally, the importance of elevating Indigenous voices in environmental justice and policymaking was stressed, along with the need for respect for and meaningful inclusion of Indigenous knowledge. Furthermore, challenges, needs and services related to upstream and downstream applications of water management were discussed, with a focus on the importance of collaboration among stakeholder institutions.

41. To conclude, the panel emphasized the importance of raising awareness of and respect for Indigenous knowledge, and to include such knowledge in consideration of water-related issues, as well as the need for data integration, capacity-building and cooperation among diverse stakeholders in order to address water and environmental challenges.

I. From water-related challenges to space-based solutions

42. In this session, water-related challenges, and successes in developing draft solutions by the Space4Water community, were presented to inspire the consecutive interactive session on the co-design of space-based solutions.

43. Challenges related to the Ngakoaohia River (Challenge ID 40: Lacking historic knowledge on vegetation cover and surface water extent/river course, and Challenge ID 41: Ngakoaohia River pollution[6]), as well as steps taken by the community since the second Space4Water stakeholder meeting[7] (held online on 11 and 12 May 2023) were presented by one of the Space4Water Indigenous voices, Cadence Kaumoana of the Te Ara Mātauranga Trust, New Zealand. Through planting, observations and water quality testing, the Māori community was able to begin the monitoring of their river.

44. With input from the participatory workshop for Indigenous women on their roles and responsibilities related to water held on 26 October 2022[8] and the second Space4Water stakeholder meeting, held online on 11 and 12 May 2023,[9] and using local expertise, surveys and historical data, the community undertook significant research to identify and track the flow and growth of the local river, water use and native plant types. This project allowed the Indigenous community to gather qualitative data and anecdotal information to inform the activities in restoring waterways and enhance vegetation planting and growth. Since the last stakeholder meeting, the community had planted 800 riparian native plants and was undertaking water quality testing for the first time in the stream's recorded history. All of those tasks had been completed by the Indigenous people of the area, involving all generations. The restoration of the river would mean a return of endemic wildlife, water quality and other associated environmental benefits. The land where the river was located could become a reserve for the local Indigenous people, who could use and restore the water of the river. Work with the local council was also to be investigated as part of the restoration project.

[6] The challenge descriptions related to this presentation are available at www.space4water.org/person/kaumoana.

[7] Second Space4Water stakeholder meeting, held online on 11 and 12 May 2023. Event website is available at www.unoosa.org/oosa/en/ourwork/psa/schedule/2023/2nd-space4water-stakeholder-meeting.html. See also the report on the meeting, conference room paper A/AC.105/2023/CRP.22.

[8] More information available at www.unoosa.org/oosa/en/ourwork/psa/schedule/2022/participatory-workshop-for-indigenous-women-on-their-everyday-lives-related-to-water.html.

[9] For more information, see A/AC.105/2023/CRP.22.

45. An update of the space-based and nature-based solution vegetation classification for land of the Māori community[10] was developed and presented by collaborators following the second Space4Water stakeholder meeting, contributing to addressing the challenge presented. The space-based approach identified that the Māori community was located at the southern part of the watershed, with their lands covering an area of 0.15 km^2. Data sources used included vegetation cover, Landsat 7 data, hydrographic maps and historical community surveys.

46. "Challenge ID 35: the Samuru tribe lack of access to safe drinking water"[11] was presented by an Indigenous member from Kenya. The Samburu community in Kenya were pastoralists who kept animals as their livelihood. They moved from place to place in search of adequate pasture lands and water. Owing to the recent dry spell, water sources were dry and there was no water. Both women and girls walked long distances of about 20 km per day to search for water. That search usually went on from day until night. To save the water they brought back home, some women and girls bathed wherever they found water. The long journeys they made in the search for and carrying water had impacted their well-being because some of them were suffering back pain. In addition, the water they collected was not as clean as to be suitable for drinking, but because they had no other options, they consumed this water, resulting in them suffering from water-related illnesses. Schoolchildren had to bring their own water in one- and two-litre bottles from their homes to school because there was no water at the school.

47. The draft solution "Water suitability map for the Samburu community"[12] was developed by the stakeholder Kenya Space Agency and a Space4Water young professional from Guatemala with a background in hydrogeology. The draft solution built on space-based information on drought and vegetation as well as geological mapping. It was presented by the collaborators and further developed in the interactive session following the presentation of challenges.

48. A presentation on droughts and floods in the same region[13] was made by a stakeholder from academia, who also presented a draft solution, entitled "A model determining optimum sites for rainwater harvesting".[14] The presenter suggested enriching and improving the model with the help of the community during the interactive session.

49. Another related presentation on space technologies to aid rainwater-harvesting that can be incorporated into the outlined solution was presented by the Prince Sultan Bin Abdulaziz International Prize for Water. Digital elevation models were used to assess dam basins and satellite data in order to strategically maximize the benefits for downstream communities.

J. From water-related challenges to space-based solutions: hands-on session to draft and co-create space-based solutions and presentations of drafted solutions

50. Participants were grouped in seven teams with two to five collaborators to co-design solutions for previously identified water-related challenges. Those challenges were collected by the Office from Space4Water stakeholders and affected Indigenous communities who took part in a participatory workshop for Indigenous women on their roles and responsibilities related to water, whose participants are now

[10] Space4Water portal, "Vegetation classification for land of Māori community", draft, 20 April 2023.

[11] Lilian Nguracha Balanga, "Samburu tribe lacks access to safe drinking water: dry spells due to water scarcity", Space4Water portal, 2 March 2023.

[12] Available at www.space4water.org/space-based-solution/water-suitability-map-samburu-county-kenya.

[13] Khalid Mahmood, "Droughts and floods over the same region", Space4Water Portal, 4 May 2022.

[14] Available at www.space4water.org/space-based-solution/determining-optimum-sites-rainwater-harvesting-development.

part of the Space4Water community and have their own profile pages listed under the "Indigenous voices" area of the portal.

51. *Draft solution for challenge ID 35: "Samburu tribe lacks access to safe drinking water"*. The group developed alternatives to the initially presented borehole siting, including rainwater harvesting and the creation of sand dams that were ideally created at locations identified using digital elevation models, precipitation monitoring and the Normalized Difference Vegetation Index.

52. *Draft solution for challenge ID 37: "Water shortages and quality issues for domestic use in Platfontein, South Africa"*. The challenge description pointed to mining as a potential source of pollution. The collaborating team suggested an additional source of pollution could be the agricultural activities and fish farming in the vicinity of the river used for the local water supply. To analyse the causes of pollution, the team suggested monitoring and evaluating chemical (pH, heavy metals), physical characteristics (turbidity, total suspended matter, Secchi depth, salinity) biological measurements (chlorophyll a), economic, and socioeconomic parameters using remote sensing and in situ data collection. Except for pH, which required on-site sampling, data for other parameters could be obtained through remote sensing.

53. The solution for challenge ID 40: "Lacking historic knowledge on vegetation cover and surface water extent/river course" and the solution for challenge ID 41: "Ngakoaohia River pollution in New Zealand" were both developed by a group of individuals, including, an Indigenous member of the Māori community facing the challenges, a young professional from the University of Texas at Arlington, a representative from the National Water and Sanitation Agency of Brazil and a representative of the University of Natural Resources and Life Sciences of Austria.

54. A draft solution for challenge ID 45: "Potential consequences due to the melting Athabasca glacier, Canada" was developed and presented by a young professional from Austria and a stakeholder representative from the Tribhuvan University of Nepal. Climate change caused the melting of the Athabasca glacier located in the Canadian Rocky Mountains. Two scenarios were considered: an excess of water due to the melting ice leading to flooding, and a water shortage. They emphasized that more data were needed on discharge and temperatures of the glacier so that they could make an inventory of snow cover and watershed area. A regression model could be used to assess the relationship between snow melt, temperature and discharge. The Hydrologic Engineering Center's River Analysis System (HEC-RAS) was the software of choice for flood modelling.

55. The draft solution for challenge ID 47: "Need for water quality data to monitor effects of mining and industrial use of water near Lake Athabasca, Canada" was co-designed by a stakeholder representative from the National Water and Sanitation agency in Brazil and a young professional from the Wollo University of Ethiopia. Data are lacking on industry water use and how it may affect the community on the north-western shore of the lake and the areas downstream from tar sands and mining extraction. In situ data need to be collected. Combined with satellite data, these allow for detecting changes in water quality and investigating possible relationship. Steps to the solution include delimiting the area of interest, identifying existing in situ data sources (e.g. samples taken at five points in time, both upstream and downstream of the activities affecting water quality) and reports, carrying out field surveys if more data are needed, producing satellite-based estimation models for the water-quality parameters, and generating time series of the data and undertaking a geographic information system analysis integrating land cover and both surface and groundwater data. Resources needed include Google Earth Engine, QGIS or ArcGIS, technical and environmental reports from the companies involved, public data sets and satellite data sets.

56. The draft solution for challenge ID 53: "Need for data on ice quality – to monitor ice thickness for security" was worked on by the Office solely, as the online participants did not connect. Research of literature on monitoring ice thickness was undertaken to identify suitable methods and sources of Earth observation data.

57. A draft solution for challenge ID 56, entitled “Droughts and floods over the same region”, was developed by the stakeholder representative of the University of the Punjab, the stakeholder representative of SUPARCO and two representatives of the Prince Sultan Bin Abdulaziz International Prize for Water. The developed model had been implemented in ArcGIS, and a volunteer to build an open-source solution was sought.

58. The Office is committed to follow up with the respective teams to continue the development and implementation of the solutions drafted and outlined in the hands-on session. The space-based solutions will be drafted, shared on the Space4Water portal,[15] and further developed during online follow-up meetings with the collaborating groups. Future stakeholder meetings will host hands-on sessions in which the collaboration will be continued.

V. Community outlook and closing

59. At the last session, chaired by the representatives of the Office for Outer Space Affairs, various views on future actions that could be initiated after the event were summarized.

60. A discussion followed, involving representatives of stakeholders and professionals, who expressed the wish:

(a) To organize a webinar series in which stakeholders and professionals present and train the community and interested parties; in the feedback form, eight presentation topics were suggested by participants for editions of the webinar;

(b) To host stakeholder meetings at stakeholder institutions, not only at the United Nations in Vienna;

(c) To create local chapters of the Space4Water project within countries to replicate the methods used in the meeting as well as its success. This had already been suggested at previous meetings. These local chapters would organize events within a country and then put forward the results to the Space4Water project. One stakeholder representative was of the opinion that creating local chapters would not necessarily increase the amount of work in countries because the Group on Earth Observations was currently creating national offices, which could prepare inputs for Space4Water.

61. A representative of the Office for Outer Space Affairs concluded the meeting by thanking all stakeholders for their most valuable contributions to this event.

VI. Conclusions

62. The third Space4Water stakeholder meeting enabled participants to have a meaningful exchange on the use of space technology for water security, water resource management, water quality and ecosystem preservation, as well as on data, systems and tools for those activities.

63. Individual follow-up with the groups who collaborated is needed to ensure the long term-success of the co-designed and co-developed space-based solutions and the sustainability and added value of the work achieved.

64. Participants were encouraged to provide written feedback using a dedicated online form. The overall rating of the event was 4.83 out of 5.

65. In the feedback form, participants expressed the value of the interactive sessions. More time was requested to interact with other community members. The webinar series could be used to cover technical presentations and thus limit delivered presentations to a minimum at future editions of the Space4Water stakeholder meeting

[15] Space-based solutions featured on the Space4Water portal are available at www.space4water.org/space-based-solutions.

provided that participants were familiar enough with the work carried out by the other participants.