II – Final report

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Project title:	
Co-Design of a hydro-meteorological information system for a sustainable water resources management in southern Africa Ko-Design eines hydro-meteorologischen Informationssystems für nachhaltiges Wasserressourcenmanagement im südlichen Afrika	

1. Deployment of funds: Work tasks and results (Verwendung der Zuwendung: Durchgeführte Arbeiten und erzielte Ergebnisse)

Water security in southern Africa (SA) is a major concern due to the high rainfall variability, projected increase of extremes including floods and prolonged droughts, and various other global stressors. Skilful probabilistic forecasts of precipitation, evapotranspiration, streamflow, and groundwater resources at lead times from days to years are an invaluable input for water resource management and early warning systems (EWS) to respond to hydro-climatic extremes.

The overall goal of Co-HYDIM-SA covering the initial and main phases is to co-design and develop a hydro-meteorological information system with SA partners, which supports the development and operationalisation of seamless climate services to augment water security but also enhance the resilience to multiple weather, climate, and water related hazards through people-centred EWS. Operationalizing pilot systems in two catchments are one primary goal for the main phase. An educational hub in meteorology and hydrology that considers the capacity development needs of academic and operational institutions is considered to support these activities. In support of this overall goals, Co-HYDIM-SA focussed in the initial phase on providing the baseline for developing a full-blown proposal allowing Co-HYDIM-SA to respond to expressed needs for hydrometeorological early warning and information systems (EWIS) to optimize water resources management and by this increase water security in southern Africa. This needs to be achieved in a transdisciplinary approach, by integrating scientific, educational and operational expertise (3-pillar approach) from Meteorology, Hydrology and Risk Assessment with the expertise of river basin authorities as well as water resources managers.

During the initial phase, the Co-HYDIM-SA consortium, together with key stakeholders from the academic, public and private sector jointly assessed the status of hydrometeorological observational networks, as well as data availability and forecasting capacities in all prioritised WASA countries. This was based on consultation with institutions being mandated to operate observation networks and issue operational forecasts. It was supported by a structured assessment of existing (multi-)model weather, climate and water resource predictions, early warning systems, and of data available for hydrological modelling, forecast verification and post-processing (Work Package (WP) 1). Based on thematic technical workshops and meetings with the National Meteorological and/or Hydrological Services (NHMS), their current operational capacities and challenges as well as measures to support their strategic plans were discussed. In workshops with academic partners, Co-HYDIM-SA prioritised to gain an overview on ongoing research and capacity development in meteorology, hydrology, and risk assessment in order to jointly develop new research goals, ideas for teaching, and

innovative operational services (WP2). Meetings with the mandated basin commissions (being responsible for the management of transboundary basins) as well as with national authorities in Angola, Botswana, Namibia, South Africa and Zambia were held to identify suitable transboundary basins (WP3) with an expressed needs for EWIS and a commitment to jointly develop a hydro-meteorological information system. In particular, the value of improved weather and climate forecasts for surface and groundwater management in target basins were discussed with stakeholders. Based on the assessment and consultation with key stakeholders including operational and academic SA partners, requirements for the information systems to be developed during the WASA main phase and the educational hub were defined (WP4) and the proposal for the main phase was jointly developed and finalised (WP5).

Besides the series of workshops and meetings, all activities of Co-HYDIM-SA were continuously supported by a strong engagement of all consortium partners to contribute to achieving the overall goal in developing a proposal which combines state-of-the-art research and technologies with on the ground capacities and needs.

1.1. Work packages

In the proposal for the initial phase, Co-HYDIM-SA aimed to address issues of research, training, and operational needs in separate workshop activities. However, it became obvious during implementation that capacities and needs cannot be separated, thus all workshop prioritised the various aims of the respective work packages. This also underlines the interconnection of all WPs. As a consequence, all workshops are summarized under WP 1

WP1: Current status of hydro-meteorological information systems, strategic plans and future needs

The main aim of this WP was the assessment of existing and planned infrastructure for hydro-meteorological observation and forecasting. Co-HYDIM-SA followed a two-fold approach consisting of an in-depth assessment undertaken together with a contracted expert and a series of workshops and meetings with key stakeholders in the region, including national and regional hydro-meteorological services.

For the assessment of existing and planned observational and forecast infrastructure, an expert has been consulted to provide a report summarising the current situation in SADC. The jointly developed report came to the conclusion that hydro-meteorological observational and forecast infrastructure is varying from country to country in southern Africa. This is partly related to different country sizes and population densities, development statuses and economies, but also policies and regulations. It was shown that National Hydrological Services (NHS) are usually less developed and operational than National Meteorological Services (NMS) in SADC which is partly related to the existing governance structures and resulting responsibilities, different financial support and technical and human capacities. NMS providing climate or meteorological services (including observation, forecast and EWS) are at advanced or fully developed level in South Africa and Zimbabwe whilst all other countries have less developed systems in place. For NHS, only South Africa provides a full range of hydrological services (incl. observation, flood forecast) while all other countries have either basic or essential services in place. The full report is attached. The outcomes of the report will be presented at the World Climate Research Programme Open Conference in Kigali in October 2023 and published in a suitable format after revision and incorporation of all workshop outcomes.

During the initial phase and following principles of 'co-design', four thematic stakeholder engagement workshops (Table 1.1) supporting knowledge exchange, mutual learning, the assessment of research, educational and technical capacities and needs of key stakeholders in southern Africa. Stakeholders were identified based on existing scientific and cooperation networks and included representatives from key Higher Education Institutions in southern Africa and Germany, national and international water and weather authorities (e.g. SADC Water, SADC CSC, WATERNET, UNDP, DMS, NMS, MALWR, SAWS, WMO, ZMD), basin organisations (CUVECOM, OKACOM, LIMCOM, ZAMCOM) and non-governmental organisations (e.g. DRFN, WWF) and private sector companies.

Table 1.1: Overview of Co-Hydim-SA technical workshops conducted during the initial phase

Workshop	**Topic**	**Type**	**Dates**	**Location**	**Participants**
Technical Workshop (WS 1)	Observational hydro-meteorological Networks: Capacities and Needs	Hybrid	31 March – 1 April 2022	Johannesburg, South Africa	24
Technical Workshop (WS 2)	Operational Forecasting and Early Warning Systems: Capacities and Needs	Hybrid	4 – 5 April 2022	Gaborone, Botswana	36
Technical Workshop (WS 3 and 4) and excursion	Research Partnerships and Study Sites	In person	27 – 28 July 2022 & 31 July + 1 August 2022	Windhoek and Oshakati, Namibia	17 14

WS1: Observational hydro-meteorological Networks: Capacities and Needs
The overall aim of this workshop was to introduce Co-HYDIM-SA to stakeholders and operators of observational hydro-meteorological networks and users of such networks to jointly identify technical, scientific and human capacities and needs in the region. The workshop addressed the full chain of observation and application including observation technologies, data processing, service provision and uptake. A particular focus was given, but not limited, to national and regional/transboundary activities in the three basins of the Cuvelai-Etosha, Limpopo, and Zambezi.
Specific Objectives were:

1. To provide an overview of Co-HYDIM-SA, its goals and implementation approach to potential project partners,
2. To explore technical, scientific and human capacities and needs of operators of hydro-meteorological networks in the region, including weather, surface and groundwater monitoring networks, with focus on the three basins and at national and regional scale,
3. To identify needs in data provision and integrated climate-hydrogeological modelling by practitioners, service providers and policy makers,
4. To establish the mechanism and pathways for developing a fundable proposal incl. share of responsibilities.

WS2: Operational Forecasting and Early Warning Systems: Capacities and Needs
The overall aim of this workshop was to introduce Co-HYDIM-SA to stakeholders and operators of operational meteorological and hydrological forecasts and Early Warning systems to jointly identify technical, scientific and human capacities and needs in the region. The workshop focussed on the full chain of forecasting and Early warning systems including

data requirements and processing, service development and implementation, accuracy/uncertainty and quality standards and the uptake of these services. A particular focus was given, but not limited, to national and regional activities in the three basins of the Cuvelai-Etosha, Limpopo, and Zambezi.

Specific Objectives were:

1. To provide an overview Co-HYDIM-SA, its goals and implementation approach to potential project partners,
2. To explore national and regional technical, scientific and human capacities and needs in the field of forecasting and early warning systems,
3. To identify data and modelling needs, infrastructural needs of service providers,
4. To establish the mechanism and pathways for developing a fundable proposal incl share of responsibilities.

WS3+4: Research Partnerships and Study Sites

The overall aim of this workshops was to identify the potential for research partnerships during the main phase. Thus, the workshops discussed fields of collaborations in academic and non-academic education, scientific exchange and mobility, workshops and contributions to the SASSCAL Graduate Studies programme and others.

Specific Objectives are

1. To provide an overview of Co-HYDIM-SA, its goals and implementation approach to potential research partners,
2. To discuss contributions of identified potential technical and research partners to Co-HYDIM-SA, especially regarding climate services and early warning systems,
3. To conceptualise the Co-HYDIM-SA Educational Hub,
4. To identify links and complementary actions in support of SASSCAL GSP and other regional training programmes (e.g. WATERNET),
5. To identify potential study and implementation sites including a field trip and visit to the CUVECOM Office in Oshakati (northern Namibia),
6. To establish the mechanism and pathways for developing a fundable proposal incl. share of responsibilities and identifying preliminary task areas and task teams.

The workshops and meetings provided in-depth insights in existing capacities which complemented and detailed the outcomes from the assessment report. Despite existing but underdeveloped capacities in hydro-meteorological service development and provision in the region, with South Africa being on the forefront, it can be concluded that stakeholders in southern Africa have urgent needs in terms of supporting the improvement of human, scientific, technical and operational capacities. A summary of the needs expressed during the workshop outcomes is provided in Table 1.1. A full overview of existing capacities and needs is provided in the workshop reports.

Table 1.1: Summary of identified needs resulting from the technical workshops and meetings

Field	Needs/support
Observation	All hydrological services expressed needs for gauging station, particularly support for new stations, the rehabilitation and upgrade of existing stations to real-time data and support for maintenance. All meteorological services have formulated needs in improving the existing observational network by additional automatic weather stations, but also support for calibration, maintenance, and upgrades. The discussions have highlighted that there is need to improve capabilities and skills in Earth-Observation (EO)-based monitoring of climate and hydrological parameters (e.g. rainfall, humidity, water extent, quality etc).
Data scarcity	All participating stakeholders agreed that the improvement of data availability (high spatial and temporal resolution) for research and operations is key for better forecasting and operational early warning in southern Africa. This includes amongst others observation (station data, EO-based data), model data (historic, current, projection), but also data rescue.
Forecasting	There is a huge demand in introducing and improving forecast technologies, including modelling and postprocessing capacities and by this improving hydro-climatological service portfolios at national and regional level.
IT Infrastructure	A strong demand exists in providing computing infrastructure including High Performance Computers, tailored software solutions and affordable access to cloud services.
Early Warning	Early warning is underdeveloped in southern Africa, thus support is needed in better predicting extreme events (droughts, floods, hazards), to provide information on agricultural seasons (onset, cessation, length) and the seasonal/sub-seasonal water availability across the region. Here even basic information are lacking and thus were requested.
Hydrological Modelling	Modelling capacities in the region are limited, hence, needs were expressed in improving human, technical and scientific capacities for transboundary groundwater as well as surface/subsurface modelling.
Capacity development	Various stakeholders expressed interest and needs in technical training to staff (e.g. LIMCOM, DMS, SADC) in data management as well as observation and modelling technologies. There is also a deficit in academic training, and here particularly in water economics and governance. In addition, stakeholders expressed needs for support in science communication.
Key areas	Altogether three major target areas were defined during the workshops and based on the input from key stakeholders. These include the Limpopo Basin (here with a focus on the upper Limpopo, i.e. Notwane catchment), the Cuvelai-Etosha-Basin and the Chobe River basin (Zambezi). Due to the limits of available funds, the consortium agreed to focus on the Notwane catchment and the Cuvelai-Etosha-Basin in the first main phase, but with the potential to scale up in a second main phase.

Impressions from the workshops and meeting are shown in Figure 1.1.

Figure 1.1: Impressions from the Co-Hydim-SA technical workshops and meetings (A: Johannesburg, B: Gaborone, C: Windhoek, D: Oshakati)

WP2: Identification of academic partners for joint research and capacity development

The work package aimed at identifying of relevant academic and science partners in southern Africa and provide a platform for fostering existing and developing new science and academic partnerships. Therefore, outbreak sessions were organised as part of the workshops allowing participants to brainstorm new ideas, concepts, methods and joint activities. Resulting from these meetings, some concrete activities have started and are currently implemented.

- KIT and Stellenbosch University are currently investigating the potential and limitations of satellite-based rainfall products for the western Cape region and outlined a structure for a manuscript to be submitted to a high-ranked journal in 2023.
- KIT and Stellenbosch continued hydrological modelling work and have jointly developed a new concept for integrating isotopes in hydrological modelling to improve model robustness when modelling climatic extremes (Watson et al. 2023).
- ICWRGC and MALWR Namibia have jointly submitted a proposal to WMO in order to receive funding for improving weather monitoring in Namibia. Although the proposal was not granted, the collaboration will be utilised to explore other funding channels.
- KIT has supported the Division Groundwater at MALWR Namibia in developing and submitting a proposal to SADC-GMI in order to receive funding for improved groundwater management in Namibia. The proposal is currently in review.

The University of Namibia and the Stellenbosch University in South Africa were identified as suitable academic partners and were included as full additional full partners in the main phase proposal (Table 1.2). Identified associated partners of the main phase are the Universities of Zambia, of Pretoria, of Leeds and Santa Barbara (see Table 1.3). In terms of

capacity development, cooperation is foreseen, amongst others, with SASSCAL, Waternet, and ZEF (Table 1.3)

WP3: Identification of transboundary basins as a regional focus

The aim of this WP was to identify transboundary basins for which an explicit interest for the development of a hydro-meteorological information system incorporating data management, modelling technologies, risk assessments and early warning was expressed. After mapping the existing infrastructure and structured discussions with basin organisations and national authorities, four basins (namely Cuvelai-Etosha-Basin, Upper Limpopo catchments, Zambezi basin, Chobe Basin) were prioritised for which the data situation, governance structures, existing development plans and previous research was assessed. Based on the expected limitations of available funds for the first main phase, two transboundary reference catchments were eventually selected, namely Cuvelai-Etosha-Basin (Namibia/Angola) and the Notwane catchment in the upper Limpopo (Botswana, South Africa) which fulfilled all requirements as formulated by the Co-HYDIM-SA consortium. It needs to be noted that CUVECOM operates a fairly newly established secretariat, thus all activities are planned to directly support its further provision of operational services to the people and by this supporting its establishment as a regional service provider fulfilling its mandate to improve people's livelihood and the resilience against climate change impacts.

For the main phase, it is foreseen that the hydro-meteorological information systems will be co-developed, together with the basin authorities, for both transboundary references catchments as a regional focus, but hydro-meteorological forecasts will be developed for all WASA countries and will be tested in both reference catchments. The regional forecast can also be made available to other WASA projects if required.

WP4: Co-design of a hydro-meteorological information system

The main aim was to meet with potential end-users active in the target basins to identify specific needs related to early warning and hydro-meteorological information sharing. Here, an integrated approach was followed to address the three pillars of Co-HYDIM-SA, namely research, training and operations, as they also are highlighted in the WASA programme. Technical meetings were conducted with CUVECOM, located in Oshakati, Namibia, and Water Utility Cooperation (WUC), Botswana (Figure 1.2) to explicitly discuss the specific needs for improving water management by advanced hydro-meteorological information systems in both reference catchments. Those structured discussions build addressed the various aspects as summarised in Figure 1.2

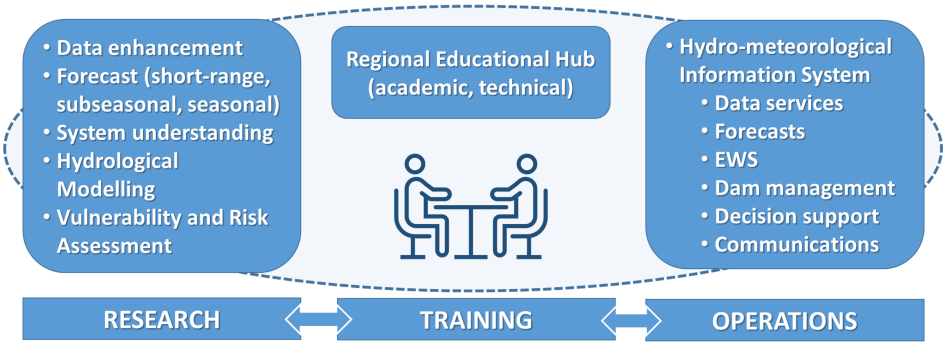

Figure 1.2: Discussion points for meetings with potential Co-HYDIM-SA end-users from CUVECOM and WUC, Botswana.

The technical discussion with CUVECOM (Figure 1.3) served to detail requirements and conceptualise the Cuvelai-Basin Early Warning and Information System (CUVEWIS) in terms of basic functionalities and information content. It became evident that a basic need is to primarily address droughts and their monitoring and seasonal forecasting in order to inform the agricultural sector in due time and initiate measure to respond to prolonged droughts. However, also flood alerts should be included given its relevance for peoples activities and potential damages for critical infrastructures. The technical meetings with WUC aimed to identify specific needs to improve dam management. Here, it became evident that there is an urgent demand of improving management by introducing dry spell forecasting in the management scheme allowing the dam operator to respond by optimising water supply and demands request from other supply systems in time. Despite the uncertainties acknowledged, the forecast of heavy rains, potentially causing floods, are of interest to be included in the information system. This should be supported by tailored modelling approaches.

Figure 1.3: Meeting of Co-Hydim-SA partners with CUVECOM staff at CUVECOM headquarters in August 2022

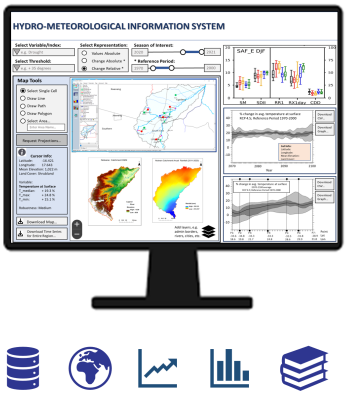

Figure 1.4: Concept for a dam management system for WUC including modelling and forecast technologies

WP5: Joint proposal writing for the main phase

The aim of this WP was to assure the joint development and submission of a proposal for the WASA main phase which takes capacities and needs of stakeholders to improve water management into account. Based on the outcomes of the needs assessment, the technical workshops and numerous individual meetings with key stakeholders a dedicated team of partners consisting of science and academic partners, public and private sector stakeholders and practitioners as well as international organisations was formed to jointly develop such proposal.

The consortium being actively involved in developing the approach for the main phase is listed in the following Table 1.2. All activities as proposed in the submitted proposal are supported by various associated partners as listed in Table 1.3.

Tabel 1.2: Core project consortium of Co-HYDIM-SA for the WASA main phase

No.	Institution	Type	Country
1	Institute of Meteorology and Climate Research – Department Troposphere Research (IMK-TRO), Karlsruhe Institute of Technology (KIT)	Research Centre, University	GER
2	Department of Earth and Environmental Sciences, Botswana University of Science and Technology (BIUST)	University, OR Tambo Chair	BOT

3	International Centre for Water Resources and Global Change (ICWRGC)/BfG	International Organisation	GER
4	Deutscher Wetterdienst (DWD)	National Weather Authority	GER
5	Department of Geography, University of Bonn (UoB)	University	GER
6	Cuvelai Watercourse Commission (CUVECOM)	International Organisation	NAM, ANG
7	Institute of Physical Geography, Goethe University Frankfurt (GUF)	University	GER
8	University of Namibia (UNAM)	University	NAM
9	Institute of Meteorology and Climate Research – Atmospheric Environment Res. (IMK-IFU, KIT)	Research Centre, University	GER
10	ALITIQ	SME	GER
11	Stellenbosch University Water Institute (SUN)	University	RSA
12	WATERNET	International Organisation	SADC
13	Water Utilisation Cooperation Botswana (WUC)	National Water Authority	BOT
14	D-One	SME	NAM
15	Splenor Solutions	SME	NAM

Table 1.3: Associated technical partners (TP), stakeholders (SH) and end-users (EU) of Co-HYDIM-SA (alphabetic order)

Partner	**Country**	**Roles**	**Engagement**	**WP**	**Commitment**
DMS (Bot)	BOT	TP, SH, EU	Regional meteorological forecast	2,3,6	verbal
DWS (Bot)	BOT	TP, EU	Forecast, operational services	3	LoI
CHC	US	TP	Data improvement, rainfall products	2,3,4	LoI
GABHIC	ANG	TP, EU	Data mining, link to national systems	1,4,6	LoI
LIMCOM	INT	SH, (EU)	Operational services, water management	2,3,6	verbal
MAWLR	NAM	TP, EU	Data mining, data/result beneficiary	1,4,6	LoI
NAMWATER	NAM	TP, EU	Data mining, data/result beneficiary	1,4,6	verbal
NMS (Namibia)	NAM	TP, EU	Regional meteorological forecast	2,6	verbal
NUST	NAM	TP	SGSP	6,7	verbal
SADC CSC	INT	TP, SH, EU	Climate service, Forecast	1,2,6	verbal
SADC Water	INT	SH	Water governance Cuvelai-Cunene	4	verbal
SASSCAL	INT	TP	Data mining, Capacity Building	1,6	verbal
ULEEDS	UK	TP	Forecast, Early Warning	2	LoI
UNDP	INT	TP, SH	CUVEWIS	4	LoI
UNESCO IHP-9	INT	SH	Educational Hub	6	verbal
UNZA	ZAM	TP	Capacity Building	6	LoI
UPretoria	SA	TP	Seasonal forecasting	2	LoI
WMO	INT	SH	EW4All, data exchange	2,6	verbal
ZEF	GER	TP	Academic training	7	LoI

The proposal writing phase started in November 2022 by drafting a first structure and ideas synthesised from the workshop outcomes. Following principles of co-design, the proposal draft was shared in various iterations with the consortium and future partners. This was

supported by various individual meetings (physical and online) to tailor the respective components of the proposal for the main phase. In conclusion, a proposal aiming at the development and operationalisation of co-designed hydrometeorological prototype EWISs that integrate near-real-time monitoring and seasonal and sub-seasonal forecast for water management in a changing climate. This will be achieved in a transdisciplinary approach, by joining scientific, academic and operational expertise from Meteorology, Hydrology and Risk Assessment, and by a co-design approach driven by river basin authorities, water resource and dam managers. The innovative aspects are (a) to tap into the novel opportunities of S2S hydrometeorological forecasting, (b) to substantially improve the skill and details of seasonal forecasts, c) to link hazard monitoring and forecasting to actual risk reduction and (d) to provide a "proof of concept" of improved monitoring and early warning of major hydroclimatic components in two transboundary catchments, the Cuvelai-Cunene and upper Limpopo. Some of these activities are proposed to be conducted in all countries covered by the WASA call whilst the case studies are expected to serve the development of prototype systems. The proposed WPs and their interlinkages are outlined in Figure 1.5. The jointly developed proposal was submitted by the partner consortium in time (15. June 2023).

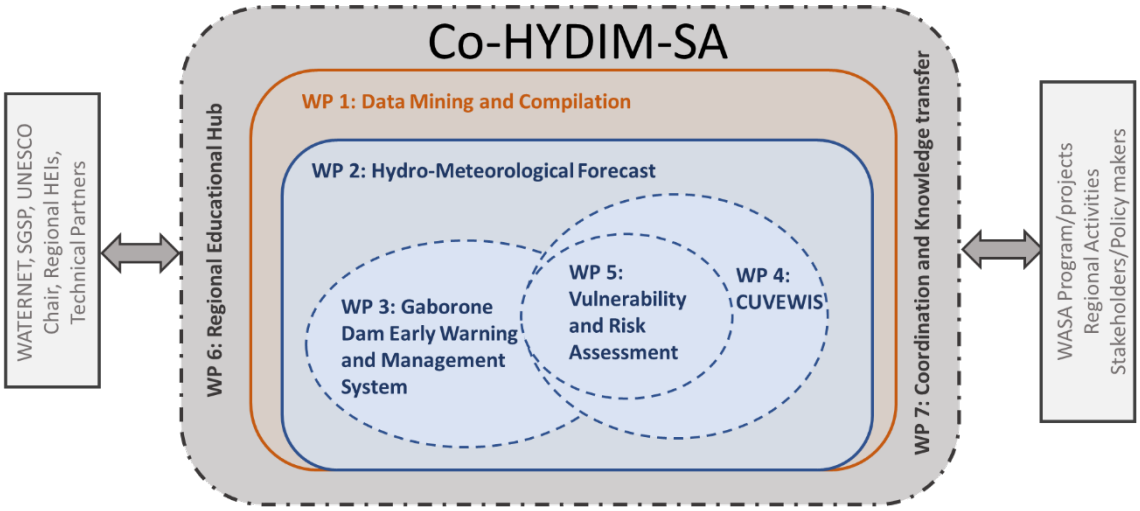

Figure 1.5: Work programme and integration of work packages

Motivated by the engagement with the WASA-funded projects and partners in Germany and SA, a consortium with the German water Partnership (GWP), SANWATCE/NEPAD, the Stellenbosch University Water Institute and KIT was formed to apply for the WASA transfer and network project. A proposal suggesting the establishment of a tandem approach to support the WASA programme in its integration, implementation and dissemination was submitted in parallel.

1.2 Synthesis of results and lessons learnt

a) Synthesis

Based on the Co-Hydim-SA activities, a full overview of capacity and needs was compiled. In summary, the initial phase corroborated that stakeholders in southern Africa require tailored near-real-time hydrometeorological information and forecasts at sub-seasonal and seasonal (up to 7 months) lead times for co-design as well as co-production of services and products in the basins and countries such as tools for dam and reservoir operations or basin-wide EWIS. This includes an appropriate communication of forecast uncertainties and user-

friendly visualisation to support decision-making for drought and flood risk mitigation. The initial phase also clarified that there is a need for water resources/ balance assessments. In the data-scarce basins of southern Africa, remote-sensing information can be exploited by available (global) hydrological models to assess water resources, including near-real-time monitoring and forecasts (Hosseini-Moghari et al. 2020)[1]. This approach provides information on soil moisture, groundwater resources and streamflow that can be utilized in basin-specific EWIS. To reduce the risk of water-related problems and improve water security by EWIS, it is necessary to understand the vulnerabilities of affected risk systems and their adaptation options. The suitability of EWIS for the decision-making in water management and thus risk reduction must be investigated but has rarely been done. Also, there is a lack of systematic research on the dependencies and interrelations of vulnerability aspects. The proposed project will therefore apply a balanced approach taking existing capacities and identified needs into account (Figure 1.6).

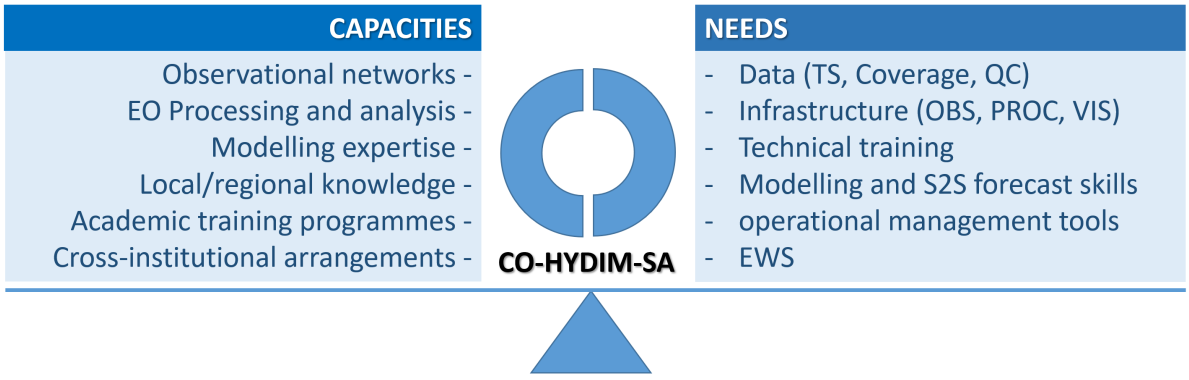

Figure 1.6: Linking existing capacities and identified needs in a balanced approach of Co-Hydim-SA.

Tackling the above described challenges and needs, Co-HYDIM-SA aims to implement an integrated approach linking research, training and operations at various levels during the main phase. Research will be conducted at regional and basin scales to demonstrate the potential of hydrometeorological monitoring and forecast for regional and local decision-makers. At the regional level, improved hydrometeorological monitoring and forecasting will be generated to showcase their effectiveness to national and regional water authorities. At local scale, this potential will be utilised for co-designing early warning and information systems for water managers which will be deployed as operational services in two reference catchments. In the upper Limpopo, Co-HYDIM-SA will co-develop a management system with an incorporated early warning component supporting improved dam management. This work will be supported by the development of innovative tools for hydrological modelling, effective communication, and data processing as well as contributions to improve the Botswana drought monitor. In the second pilot, Co-HYDIM-SA will operationalise the CUVEWIS which will provide early warning features related to drought and flood monitoring and forecast complemented by risk and vulnerability assessments. This will be supported by tailored training support for SASSCAL GSP and WATERNET which will also be achieved through the establishment of a regional educational hub.

The initial phase further served to conceptualise a holistic and structured approach on how Co-HYDIM-SA can be developed over the entire WASA-programme life cycle. Here, all

[1] doi:10.5194/hess-24-1939-2020

activities carried out with the strategic and technical partners will be interlinked and build on each other as shown in Figure 1.7.

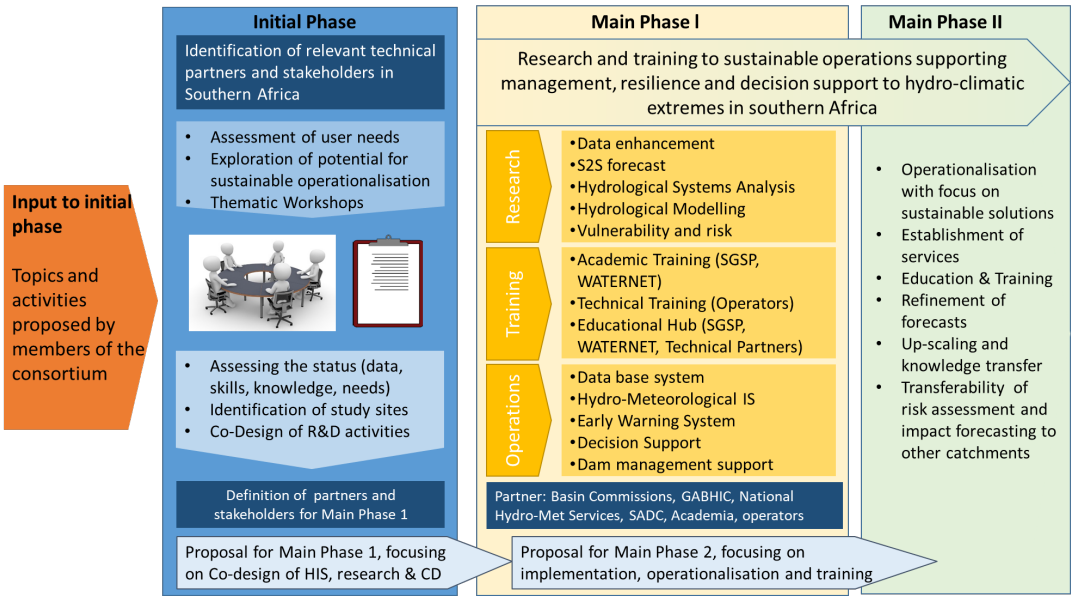

Figure 1.7: Holistic and structured approach of Co-HYDIM-SA over the entire WASA-programme life cycle.

ii) Lessons learnt

The implementation of Co-Hydim-SA and the development of a joint proposal built on a 'Co-design' approach has demonstrated that a multitier approach integrating literature review, workshops and meetings, individual meetings with key stakeholders as well as the direct exchange with technical partners and stakeholders is mandatory to receive a full oversight on existing human and technical capacities as well as research, educational and operational needs to provide tangible, innovative hydro-meteorological services supporting a better water resources management in southern Africa. This builds the basis to jointly develop science-based and needs-driven solutions which receive acceptance amongst end-users and, by this assure sustainability beyond project scopes. Co-HYDIM-SA was able to successfully implement such approach by finalising and submitting a high-quality project proposal for the WASA main phase.

The Co-HYDIM-SA consortium is convinced that the approach of funding an initial phase for an implementation driven programme such as WASA is an excellent approach which not only supports preparatory work required to develop an high-quality project in a co-design approach, but also allows to build trust amongst partners. In addition, an initial phase sets incentives and motivates partners to form strategic research partnerships, supports training and education and the continuous exchange of knowledge with public entities in southern Africa. Particularly the latter often requires time to interact due to the limited flexibility and timely approval procedures.

2. Financial Statement

The financial statement is currently work in progress by the KIT administration and Finance Department and will be finalised and submitted by end of August 2023. However, it can already be concluded from the intermediate reports, that funds were spend according to the

finance plan including costs for personnel, workshops, travel, overall expenses and a sub-contract, which require minor re-allocations due to slightly higher costs for personnel and travel.

It should also be noted that Co-HYDIM-SA agreed on a voluntary reduction of €5000 of the overall funds as requested by PT-DLR. This reduction was compensated by additional financial support from KIT funds to assure that all activities could be performed at highest scientific and technical standards as proposed in the proposal.

3. Demand and Appropriateness of the work

Co-HYDIM-SA addresses an urgent need for linking science-based drought, flood, and water resource monitoring as well as seasonal and sub-seasonal forecasts with operational service providers and users. Serving the full range from improving the data coverage, data processing, monitoring, modelling and forecasting, EWS to risk assessment and mitigation, and translating them to actionable information services, Co-HYDIM-SA contributes to improving resilience against droughts and floods in a data-scarce region. It increases the capacities for developing, utilising, and communicating improved forecasts and supports decision-makers in managing water hazards. With its approach, Co-HYDIM-SA directly addresses inter-/national efforts the SADC Regional Indicative Strategic Development Plan 2020-2030[2], the SADC Vision 2050[3], German Africa Policy Guidelines (2019)[4], the BMBF Africa Strategy (2018)[5], the BMZ Africa Strategy (2023)[6], IPCC (2021/22)[7] and the WMO EW4All Initiative (2022/23)[8].

4. Expected utilisation of results

4.1 Economic prospects after the project

Because of the aims of Co-HYDIM-SA during the initial phase, no direct economic prospects were envisaged. However, it can be concluded that Co-HYDIM-SA already has set incentives for joint collaborations with national service providers and research institutions leading to efforts to jointly submit for additional funding for interventions in various areas.

4.2 Scientific and/or technical prospects after the project

Based on the pilot character and aims of the project, Co-HYDIM-SA was not expected to generate new scientific knowledge, but provide the basis for the co-development and operationalisation of hydro-meteorological information systems for the first WASA main phase. With reference to the expressed interest and the support from the partner institutions in Germany and southern Africa it can be expected that Co-HYDIM-SA will be delivering high-quality science and training in the context of the development, application and operationalisation of innovative forecast and modelling approaches for an improved and optimised water resources management in southern Africa and, by this, contributes to improve water security in the region.

4.3 Scientific and economic implications

[2] https://www.sadc.int/document/sadc-regional-indicative-strategic-development-plan-risdp-2020-2030-english,
[3] https://www.sadc.int/document/sadc-vision-2050
[4] https://www.auswaertiges-amt.de/en/aussenpolitik/regionaleschwerpunkte/afrika/afrika-leitlinien-node
[5] https://www.bmbf.de/bmbf/de/europa-und-die-welt/vernetzung-weltweit/afrika-und-naher-osten/die-afrika-strategie-des-bmbf/die-afrika-strategie-des-bmbf_node.html
[6] https://www.bmz.de/de/laender/bmz-afrika-strategie
[7] https://www.ipcc.ch/report/ar6/wg1/, https://www.ipcc.ch/report/ar6/wg2/
[8] https://public.wmo.int/en/earlywarningsforall

With the finalisation of the initial phase of Co-Hydim-SA the requirements for co-developing and submitting a high-quality and innovative proposal for the WASA main phase were fulfilled. Submitting a proposal on 15th of June 2023 which addresses innovative and relevant scientific and technical aspects in the perspective of the co-development and operationalisation of tailored and needs-driven hydro-meteorological information systems at national and regional level, the scientific and economic continuation can be assured (in case of funding of Co-Hydim-SA during the first WASA main phase).

The proposal was supported by numerous letters of intent and verbal commitments from the technical and associated partners across Africa and Germany, namely national service providers in Namibia (e.g. MALWR, NAMWATER), Angola (GABHIC) and Botswana (DMS, WUC), academic partners from Zambia (UNZA), Namibia (UNAM), South Africa (University of Pretoria, SAWS) and WATERNET as well as international institutions such as the basin organisations (CUVECOM, LIMCOM, OKACOM), SASSCAL, SADC CSC and SADC Water.

5. Progress in the field in collaboration with other parties

Joint research with African partner institutions in the field of hydrological modelling and the assessment of satellite-based rainfall products which were conducted in support of Co-Hydim-SA have already generated scientific outcomes which are partially published or will be published timely. Furthermore, the report current status of observational and forecasting infrastructure and systems in southern Africa will be revised after presenting it at the World Climate Research Programme Open Science Conference and published in a suitable format.

During the implementation of the initial project for Co-Hydim-SA, various collaborations have been initiated by consortium partners. As described under WP 2, KIT has established research partnerships with Stellenbosch University and University of Pretoria in the field meteorological forecast and rainfall modelling. ICWRGC has supported MALWR in the development and submission of a joint proposal to improve hydro-meteorological monitoring. KIT has also supported the Groundwater division at MALWR in developing and submitting a proposal to improve ground water management in the country. Also, KIT has agreed on a close collaboration with the Climate Hazard Centre at the University of Santa Barbara which will address mutual scientific and technical support to improve seasonal and sub-seasonal forecast for East and southern Africa. Another collaboration is foreseen with the WISER Early Warnings for Southern Arica (EWSA) project lead by the University of Leeds (UK).

6. Accepted and planned publications

6.1 Journal publications:

Watson, A., Vystavna, Y., Kralisch, S., Helmschrot, J., van Rooyen, J., Miller, J., (2023): Development of an isotope-enabled rainfall-runoff model: Improving the capability to capture hydrological and anthropogenic change. Hydrological Processes. 2023;37:e14819. Doi: 10.1002/hyp.14819. (IF: 3.554)

Speranza, C.I, Akinyemi, F.O., Baratoux, D., Benveniste, J., Ceperley, N., Driouech, F., Helmschrot, J. (2022): Enhancing the uptake of earth observation products and services in Africa through a multi-level transdisciplinary approach. Surveys in Geophysics. Doi: 10.1007/s10712-022-09724-1. (IF: 7,97)

Watson, A., Midgley, G., Ray, P., Kralisch, S., Helmschrot, J. (2022): How climate extremes influence rainfall-runoff model performance and uncertainty: implications for future

climate change assessments for Mediterranean, Southern Africa. Frontiers in Climate 4:859303. doi: 10.3389/fclim.2022.859303.
Kapuka, A., Hlásny, T, Helmschrot, J (2022): Climate change research in southern Africa in recent two decades: Progress, needs and policy implications. Journal of Regional Environmental Change 22 (18). Doi: 10.1007/s10113-022-01886-3. (IF: 3.678)

6.2 Conference presentations:

Helmschrot, J., Fink A. (2023): An assessment of observational and forecasting infrastructure and Early Warning Systems in southern Africa and its implications for improving hydro-meteorological services. WCRP Open Science Conference, Kigali, Rwanda, 23-27 October 2023 (accepted).
Helmschrot, J., Thompson, S., Hatutale, A.-L., Mostert, A. (2023): Impact of climate extremes on dam operations and consequences for a forecast-driven dam management in Namibia. WCRP Open Science Conference, Kigali, Rwanda, 23-27 October 2023 (accepted).
Watson, A., Miller, J., Helmschrot, J., Kralisch, S. (2023): A systematic approach to improve hydrological modelling of anthropogenic and climate change impacts in at-risk catchments. 28th IUGG General Assembly, Berlin, Germany, 11-20 July 2023 (accepted).
Helmschrot, J., Thompson, S., Hatutale, A.-L., Mostert, A. (2023): Climate trends and projected climate change and its implications for new approaches in dam management in Namibia. 28th IUGG General Assembly, Berlin, Germany, 11-20 July 2023 (accepted).
Helmschrot, J. (2022): Climate Change and Water Security (Keynote). African Regional Forum on Climate Change Stellenbosch, South Africa, 5 – 9 September 2022.

6.3 Reports

Co-HYDIM-SA (2023): Current status of observational and forecasting infrastructure and systems in southern Africa. 33 pgs. (unpublished)[9].

[9] The outcomes of this study will be presented at the WCRP Open Science Conference (https://wcrp-osc2023.org/) and after revision published.