Developing decision maker capabilities for robust and adaptive water planning

SUPPLEMENTARY MATERIALS

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Identifying minimum information requirements to improve integrated modeling capabilities: lessons learned from Dynamic Adaptive Policy Pathways

A. Supplementary Material – Chapter 3

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1. Models integrated to Basin Futures

1.1. Model considered (calculation-based solutions) to estimate adaptive tipping points for the rural incomes' objective

Conditions of failure for the actions supportive of the rural incomes' objective are based on the reliability of the water supply to irrigation. A threshold of 85% efficiency is considered (1 failure in 5 years). In addition, a priority in water allocations is considered: first for D&I water uses (including livestock water demand) and then, irrigation demand.

The reliability of the supply for the whole basin within a year *y* is given by:

$$Supply_{r,t} = BW_{r,t} - Env_{r,t}$$

$$rel\_supply\_rural\_sc_{t,y} = \frac{1}{7} \times \sum_{r} \frac{1}{12} \times \sum_{m} n_{supply\_irr\_sc,r,t,m}$$

Where:

$Supply_{r,t}$ is the total available freshwater supply (m^3),

$BW_{r,t}$ is the blue water availability (m^3),

$Env_{r,t}$ is the water released for aquatic systems (m^3),

$rel\_supply\_rural\_sc_{t,y}$ is the supply reliability for irrigation (%) in year *y*, and

$n_{supply\_irr\_sc,r,t,m}$ is the number of months in a year for which the supply exceeds or is equal to water use demands.

When considering the two State Government, the reliability of the supply for a year *y* is given by:

$$rel\_supply\_rural\_sc_{Jharkhand,t,y} = \frac{1}{4} \times \sum_{r=1}^{4} \frac{1}{12} \times \sum_{m} n_{supply\_irr\_sc,r,t,m}$$

And

$$rel\_supply\_rural\_sc_{Odissa,t,y} = \frac{1}{3} \times \sum_{r=5}^{7} \frac{1}{12} \times \sum_{m} n_{supply\_irr\_sc,r,t,m}$$

Where:

$rel\_supply\_rural\_sc_{Jharkhand,t,y}$ and $rel\_supply\_rural\_sc_{Odissa,t,y}$ are the reliability of the supply (%) in a year y for the State or Jharkhand and the State of Odissa respectively.

1.2. Models considered (calculation-based solutions) to estimate the performance of adaptation pathways

1.2.1. Rural incomes' objective

1.2.1.1. Crop model for irrigation

The model aims at considering costs associated to arable land suitability and the relative change in water productivity between two consecutive periods, and to derive crop specific water demand to estimate green water (ETc irrigation) and the green blue water scarcity indicator used as a proxy for population health. The latter parameter is detailed further under section 2.4.

Four scenarios (*sc*) are considered:
bau1: existing and on-going major and medium dams with an irrigation growth rate of 165% over 25 years.
bau2: existing, on-going, and proposed major and medium dams with an irrigation growth rate of 165% over 25 years.
bau1: existing and on-going major and medium dams with an irrigation growth rate of 208% over 25 years.
bau2: existing, on-going, and proposed major and medium dams with an irrigation growth rate of 208% over 25 years.
Irrigated crop actual evapotranspiration is calculated based on a crop coefficient approach (Doorenbos & Pruitt, 1977):

$$ETactual\_irr_{c,r,t,g} = \sum_{m} K_c \times ET_{r,t,m} \times \frac{n_{growingdays,m}}{n_{monthdays,m}}$$

Where:
$ETactual\_irr_{c,r,t,g}$ is irrigated crop actual evapotranspiration over its growth duration g (mm/growing cycle),
K_c is a time invariant crop coefficient, and
$ET_{r,t,m}$ is the potential evapotranspiration (mm/month), with partial months included pro-rata with $n_{growingdays,m}$ out of the total $n_{monthdays,m}$ for month m.

For a year during a period *t* and for a reach *r*, irrigated crop actual evapotranspiration is given by:

$$ETactual\_irr_{c,r,t,y} = \sum_{g} ETactual\_irr_{c,r,t,g}$$

Where:

$ETactual\_irr_{c,r,t,y}$ is the sum of a crop actual evaporation based on its planting time and throughout a year (mm/year).

Based on irrigated crop annual yields provided by the Basin Futures tool, the planted area, and the consideration of a factor for irrigated land suitability, irrigated crop incomes are given by:

$$I\_irr\_sc_{r,t} = \sum_{c} Y\_irr\_sc_{c,r,t} \times \frac{A\_irr\_inc\_sc_{c,r,t}}{A\_irr\_sc_{c,r,t}} \times P_{c,r,t}$$

With irrigated land area considering a suitability factor given by:

$$\begin{aligned} &A\_irr\_inc\_sc_{c,r,t} \\ &\qquad = A\_highly_{r,t} + A\_moderate_{r,t} \times 0.75 + A\_marginal_{r,t} \times 0.50 \\ &\qquad + A\_bad_{r,t} \times 0 \end{aligned}$$

Where:

$I\_irr\_sc_{r,t}$ is the total net incomes from irrigated crop production in 2000 USD$,

$Y\_irr\_sc_{c,r,t}$ is irrigated crop yields (t),

$A\_irr\_inc\_sc_{c,r,t}$ is the irrigated planted area accounting for the potential impact of soil suitability (ha),

$A\_irr\_sc_{c,r,t}$ is the planted irrigated area without accounting for land suitability (ha),

$P_{c,r,t}$ is the crop price (USD$ in 2000/t),

$A\_highly_{r,t}$, $A\_moderate_{r,t}$, $A\_marginal_{r,t}$ and $A\_bad_{r,t}$ the arable land areas (ha) of belonging to high, moderate, marginal, and bad suitability, respectively.

The impact of changes in water productivity on irrigation net benefits for a period are given by:

$$WP\_sc_{r,t} = \frac{Y\_irr\_sc_{r,t}}{Irr\_sc_{r,t}} \times 1000$$

With:

$WP\_sc_{r,t}$ water productivity (kg/m^3),

1000 a conversion factor from t/m^3 in kg/m^3

Irrigation incomes, for the whole basin, based on the relative change in water productivity between two consecutive years are given by:

$$I\_irr\_sc_t = \sum_r I\_irr\_sc_{r,t} \times \left(1 + \left(\frac{WP\_sc_{r,t}}{WP\_sc_{r,t-1}} - 1\right)\right)$$

Where $I\_irr\_sc_{r,t}$ are the total incomes from crop production (USD$ in 2000)

When considering the two main state government in the Basin and irrigated crop net benefits:

$$I\_irr\_sc_{Jharkhand,t} = \sum_{r=1}^{4} I\_irr\_sc_{r,t}$$

$$I\_irr\_sc_{Odissa,t} = \sum_{r=5}^{7} I\_irr\_sc_{r,t}$$

Where $I\_irr\_sc_{Jharkhand,t}$ and $I\_irr\_sc_{Odissa,t}$ are irrigation net benefits (USD$ in 2000) in Jharkhand and in Odissa, respectively.

1.2.1.2. Crop model for rainfed agriculture

Rainfed agriculture does not existing in Basin Futures. Rainfed crop yields were derived from considering crop water demands, itself estimated based on climate data (Doorenbos & Pruitt, 1977). We assume that deep percolation, capillary rise, subsurface flow in or out of the root zone, and change soil moisture are not influential on crop water demands and yields, for simplification purpose. A stress factor was considered by assuming that, for mean monthly potential evapotranspiration (*pET*) < ET_0 (maximum evapotranspiration in the absence of water stress):

pET = *ETa* (crop actual evapotranspiration) for *pET*< ET_0

pET = mean monthly rainfalls for *pET* > ET_0

Water demands for rainfed crops is given by:

$$ETactual\_rain_{c,r,t,g} = \sum_{m} K_c \times ET_{r,t,m} \times \frac{n_{growingdays,m}}{n_{monthdays,m}}$$

Where:

$ETactual\_rain_{c,r,t,g}$ is a rainfed crop actual evapotranspiration over its growth duration *g* (mm/growing cycle),

K_c is a time invariant crop coefficient,

$ET_{r,t,m}$ is the potential evapotranspiration (mm/month), with partial months included pro-rata with $n_{growingdays,m}$ out of the total $n_{monthdays,m}$ for month m.

For a year during a period *t* and for a reach *r*, rainfed crop actual evapotranspiration is given by:

$$ETactual\_rain_{c,r,t,y} = \sum_{g} ETactual\_rain_{c,r,t,g}$$

Where:

$ETactual\_rain_{c,r,t,y}$ is the sum of a crop actual evaporation based on its planting time and throughout a year (mm/year).

Based on the assumption of a constant crop response factor *Ky =1*, rainfed crop yields, for a crop *c*, is given by:

$$\left(1 - \frac{Y_{c,r,t}}{Y_{max,c}}\right) = K_y \times \left(1 - \frac{ETactual\_rain_{c,r,t}}{ET_{c,r,t}}\right)$$

With:

$$Y_{c,r,t} = Y_{max,c} \times \frac{ETactual\_rain_{c,r,t}}{ET_{c,r,t}}$$

Where:

$Y_{c,r,t}$ is a crop yield (t/ha),

$Y_{max,c}$ a crop maximum yield (t/ha),

$ET_{c,r,t}$ is the maximum water demand for a crop, without soil moisture stress (mm)

Rainfed crop incomes for a reach and period is given by:

$$I\_rain\_sc_{r,t} = \sum_{c} Y_{c,r,t} \times A\_rain\_inc\_sc_{c,r,t} \times P_{c,r,t}$$

With the planting area for rainfed crops, considering land suitability, given by:

$$A\_rain\_inc\_sc_{c,r,t} = \Delta A\_highly\_sc_{r,t} + \Delta A\_moderate\_sc_{r,t} \times 0.75 + \Delta A\_marginal\_sc_{r,t} \times 0.50 + \Delta A\_bad\_sc_{r,t} \times 0$$

Where:

$I\_rain\_sc_{r,t}$ is the total net incomes from rainfed crop production in 2000 USD$,

$A\_rain\_inc\_sc_{c,r,t}$ is the re-estimated rainfed planted area accounting for the potential impact of soil suitability on rainfed crop incomes (ha),

$P_{c,r,t}$ is the crop price (USD$ in 2000/t),

$\Delta A\_highly_{r,t}$, $\Delta A\_moderate_{r,t}$, $\Delta A\_marginal_{r,t}$ and $\Delta A\_bad_{r,t}$ are the remaining arable land areas after irrigation (ha) of high, moderate, marginal, and bad suitability, respectively.

The total net benefits from rainfed agriculture for a period and the whole basin is given by:

$$I\_rain\_sc_{t} = \sum_{r} I\_rain\_sc_{r,t}$$

When considering the two main state government in the Basin:

$$I\_rain\_sc_{Jharkhand,t} = \sum_{r=1}^{4} I\_rain\_sc_{r,t}$$

$$I\_rain\_sc_{Odissa,t} = \sum_{r=5}^{7} I\_rain\_sc_{r,t}$$

Where:

$I\_rain\_sc_{Jharkhand,t}$ and $I\_rain\_sc_{Odissa,t}$ are rainfed net benefits (USD$ in 2000) in Jharkhand and in Odissa, respectively.

1.2.1.3. Fisheries model

Fisheries production and incomes are not considered in Basin Futures. Values are estimated based on considering the annual harvesting yields Y_{fish} (kg/year) for a specific basin and the market price P_{fish} (USD 2000/kg) for its associated main native fish species used for food consumption.

$$Afish\_sc_{r,t} = A\_wb_{r,t} + A\_st\_sc_{r,t}$$

Where:

$Afish\_sc_{r,t}$ is water bodies total area (ha),

$A\_wb_{r,t}$ is the area of surface water bodies (ha),

$A\_st\_sc_{r,t}$ is the total area covered by in stream major and medium reservoirs (ha)

To account for changes in harvesting yields, we considered changes in the frequency of occurrence of peak flood events (Q10) (Welcomme et al., 2006). We assume that the relative change in Q10 events compared to pre-water resources development will influence fisheries incomes.

The total net benefits from fisheries production $I\_sc_{fish,t}$ (USD 2000) for a decision point *t* and for the whole basin is given by:

$$I\_sc_{fish,t} = Y_{fish} \times P_{fish} \times \sum_{r} Afish\_sc_{r,t} \times (1 + \left(\frac{fQ10_{sc_{r,t}}}{fQ10_{sc_{r,past}}} - 1\right))$$

Where:

$fQ10\_sc_{r,t}$ and $fQ10\_sc_{r,past}$ are the frequency of occurrence of peak flood events (Q10) in a reach *r* for a period *t* and for *past* (pre-development) time, respectively.

When considering fisheries incomes for the states:

$$I\_sc_{fish,Jharkhand,t} = Y_{fish} \times P_{fish} \times \sum_{r=1}^{4} Afish\_sc_{r,t} \times (1 + \left(\frac{fQ10_{sc_{r,t}}}{fQ10_{sc_{r,past}}} - 1 \right))$$

And

$$I\_sc_{fish,Odissa,t} = Y_{fish} \times P_{fish} \times \sum_{r=5}^{7} Afish\_sc_{r,t} \times (1 + \left(\frac{fQ10\_sc_{r,t}}{fQ10\_sc_{r,past}} - 1 \right))$$

Where $I\_sc_{fish,Jharkhand,t}$ and $I\_sc_{fish,Odissa,t}$ are the net incomes from fisheries in Jharkhand and Odissa, respectively.

1.2.1.4. Land use model

Land uses in Basin Futures are provided for the current situation (2000). To account for land use and land cover changes over time, the following assumptions were considered:

Assumptions	Rationale	References
Protected areas remain the same as for 2000 estimates.	The State of Orissa's vision include the conservation of existing protected areas.	ICID, 2005
Grassland area is the same as for 2000 estimates.	Account for a fixed grassland water demand of 251 m^3/capita/year to estimate individual diet satisfaction (Green Blue Water Scarcity indices)	Xu & Wu, 2017
Waterbodies areas (except in-stream storages) are considered constant over time		Basin Futures
Urban area growth rate per decade is of 33%. Land uses are assumed to be first changed by urbanization, then irrigation and finally rainfed agriculture.	Based on the growth rate of the city of Rourekela (Pamposh) from 1991 to 2014	ISRO, n.d.
Cropland area is based on the consideration of crop planting	The growth rate varies based on the chosen future scenario (business as usual or irrigation	ICID, 2005

area growth rate from 2000 to 2025 and constrained by the command area.	development). The command area (CCA) is estimated based on the consideration of major and minor irrigation schemes in the basin and location within Basin Future reaches.	
Crop incomes are reduced based on the availability of suitable soil. Arbitrary coefficients are allocated to different soil suitability provided by Basin Futures: Highly suitable soil: 1 Moderately suitable: 0.75 Marginally suitable: 0.50 Not suitable: 0 Highly and moderately suitable lands are first assigned to irrigation, the remaining land assigned to rainfed land.	Crop yields should vary according to soil quality, assuming no fertilizer inputs.	Basin Futures
Ongoing major and medium dams are completed by 2020	Reservoir areas are used to calculate fish harvesting.	Basin Futures

The total land use area per reach *r* and a period *t* is given by:

$$LULC\_sc_{r,t} = A\_urban_{r,t} + Crop\_sc_{r,t} + A\_protected_r + A\_other\_sc_{r,t} + A\_wb_r + A\_grass_r$$

Constrain to:

$$A_{r,t} \geq LULC\_sc_{r,t}$$

Where:

$LULC\_sc_{r,t}$ (km^2) is the total land use area,

$A\_urban_{r,t}$ is the urban area (km^2),

$Crop\_sc_{r,t}$ is the total cropland area (km^2),

$A\_protected_r$ is the protected area within a reach (km^2),

$A\_other\_sc_{r,t}$ are other land uses and the remaining area after all other land uses (km^2),

A_wb_r is waterbodies' area (except in-stream storages) within a reach,

A_grass is grassland area within a reach (km^2),

$A_{r,t}$ is the total reach area (km^2).

Estimates for rural area over time and for a reach are calculated as:

$$A\_urban_{r,t} = A\_urban_{r,t-1} \times (1 + 0.33)$$

Estimated for cropland area over time and for a reach are calculated as:

$$Crop\_sc_{r,t} = (A\_rain\_sc_{r,t} + A\_irr\_sc_{r,t})/100$$

Constrain to:

$$CCA\_sc_{r,t} \geq A\_irr\_sc_{r,t}$$

$$Arable_r - (A_{irr}\_sc_{r,t} + A_{urban_{r,t}} + A_{protected_r} + A_{wb_r} + A_{grass_r}) \geq A\_rain\_sc_{r,t}$$

Where:

$A\_rain\_sc_{r,t}$ is the planted rainfed area (ha),

$A\_irr\_sc_{r,t}$ is the planted irrigated area (ha),

$CCA\_sc_{r,t}$ is the command area (ha),

$Arable_r$ is the total arable land (ha).

If $LULC\_sc_{r,t} > A_{r,t}$, rainfed land area is first reduced, then irrigated land for the total land uses area to be equal to reach area (excluding waterbodies). Grassland and existing protected areas are assumed to remain unchanged over time. This re-allocation of cropland is assumed to be representative of crop planting time (90% in the wet season and 10% during the dry one) and crop type (83% for rice and 17% for pulses) in the BRB system (ICID, 2005).

Estimates of the total land covered by other land uses is given by:

$$A\_other\_sc_{r,t} = A_r - (A_{\_wb_{r,t}} + A_{\_protected_r} + Crop\_sc_{r,t} + A_{\_urban_{r,t,}} + A\_grass_r)$$

Land uses data for the BRB system in 2000:

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Source
Urban area in 2000 (km^2)	1	36	79	52	118	13	282	Basin Futures
Protected area (km^2)	0	183	0	0	0	304	672	Basin Futures and ICID, 2005
Grass land area (km^2)	32	68	394	221	37	5	165	Basin Futures
Cropland area in 2000 (km^2)	1588	3073	1349	3376	2882	1235	4026	Basin Futures
Waterbodies area in 2000 (km^2)	20	121	29	232	1126	13	636	Basin Futures
Reach area (km^2)	2539	4916	4963	6924	7797	2486	9750	Basin Futures
Arable land for 1961 to 2100 (ha)	253161	490014	464163	690539	777560	248200	972020	Basin Futures

1.2.1.5. Rural incomes model

Rural incomes are partially represented in Basin Futures based on irrigated crop benefits from crop yields. To account for other agricultural productions in addition to irrigation benefits for crop yields, rural incomes per capita (USD$ in 2000) are based on the estimation of rainfed crop benefits from rainfed (section 2.1.2) and irrigated (section 2.1.1) crop incomes, on fisheries incomes (section 2.1.3).

Rural population growth is based on the consideration of Shared Socioeconomic Pathways (SSP_s) values for the Indian population, with assuming similar demographic trends as National ones in the basin (Jiang & O'Neill, 2017; KC & Lutz, 2017). In the context of the article, we consider a socioeconomic scenario describing increased inequalities over time (SSP4). Details about SSPs could be found in Calvin et al. (2017).

In addition, to account for migration effects associated to climate change scenarios, assuming only migration from rural to urban centers, the rural population migrating to urban areas is deduced from Xu et al. (2020) estimates as:

$$Pop\_rural_{r,t} = Pop_{r,t} \times ((1 - ssp4_t) - m_{rcp,ssp} \times (1 - ssp4_t))$$

Where:

$Pop\_rural_{r,t}$ is the rural population at a period *t*,

$ssp4_t$ is the urban share based on SSP4 scenario,

$m_{rcp,ssp}$ is the proportion of the rural population migrating to urban centers based on the chosen climate change and SSPs scenarios.

The net rural incomes per capita for:

The whole basin:

$$I\_sc_{rural,t} = \sum_{r} \frac{1}{Pop_{rural_{r,t}}} \times \left(I\_sc_{fishr,t} + I\_irr\_sc_{r,t} + I\_rain\_sc_{r,t}\right)$$

Where:

$I\_sc_{rural,t}$ is the net incomes per capita (USD$/capita in 2000),

$Pop_{rural_{r,t}}$ is the rural population at a time period *t*,

$I\_sc_{fish\,r,t}$, $I\_irr\_sc_{r,t}$, $I\_rain\_sc_{r,t}$ are the net incomes from fisheries, irrigation and rainfed agriculture (USD$ in 2000) respectively.

The State of Jharkhand:

$$I\_sc_{rural,Jharkhand,t} = \sum_{r=1}^{4} \frac{1}{Pop_{rural_{r,t}}} \times \left(I\_sc_{fishr,t} + I\_irr\_sc_{r,t} + I\_rain\_sc_{r,t}\right)$$

Where:

$I\_sc_{rural,Jharkhand,t}$ is the net incomes per capita (USD$/capita in 2000) in Jharkhand

The State of Odissa:

$$I\_sc_{rural,Odissa,t} = \sum_{r=5}^{7} \frac{1}{Pop_{rural_{r,t}}} \times \left(I\_sc_{fishr,t} + I\_irr\_sc_{r,t} + I\_rain\_sc_{r,t}\right)$$

Where:

$I\_sc_{rural,Odissa,t}$ is the net incomes per capita (USD$/capita in 2000) in Odissa.

1.2.2. Urban incomes' objective

Urban incomes are reflected by changes in urban density ratio compared to a threshold value of 7963 inhabitants per km^2, as a proxy for urban poverty (Tripathi, 2015), and based on the relative change in hydropower production compared to current estimates, as a proxy for economic impacts on services, businesses and industries. Hydropower production (MWh) data are extracted from the Basin Futures tool.

Urban density ratio is given by:

$$UD_{r,t} = \frac{1}{7963} \times \frac{Pop_{urban_{r,t}}}{A\_urban_{r,t}} - 1$$

Where:

$UD_{r,t}$ is the urban density relative ratio compared to the threshold value (inhabitants per km^2)

$Pop_{urban_{r,t}}$ is the urban population in a reach *r* for a period *t*

$A\_urban_{r,t}$ is the area covered by urban centers in a reach (km^2)

Hydropower production ratio is given by:

$$Hydro\_ratio_{r,t} = \frac{Hydro_{r,t}}{Hydro_{r,t-1}} - 1$$

Where:

$Hydro\_ratio_{r,t}$ is the relative change in hydropower production (MWh) between two consecutive periods.

$Hydro_{r,t}$ is the mean annual hydropower production (MWh)

Values for the two proxies for urban incomes are given by:

For urban density ratio:

$$UD_{urban_t} = \sum_r UD_{r,t}$$

Where:

UD_{urban_t} is the average urban density ratio for the whole basin (*r* =1 to 7), the state of Jharkhand (*r* =1 to 4), and the state of Odissa (*r* =5 to 7)

For hydropower production ratio:

$$Hydro\_ratio_t = \sum_r Hydro\_ratio_{r,t}$$

Where:

$Hydro\_ratio_t$ is the average hydropower production ratio for the whole basin (*r* =1 to 7), the state of Jharkhand (*r* =1 to 4), and the state of Odissa (*r* =5 to 7)

1.2.3. Aquatic systems health's objective

Basin Futures already consider different indicators to estimate ecological impacts in a basin. Among the indicators used is the Blue Water Scarcity one. To account for specific allocations for the environment, this indicator was modified to indirectly evaluate the risk for aquatic ecosystems' health based on the consideration of available water resources for consumptive uses, including livestock water requirements, corresponding to the difference between the whole water resources available in the basin and flows for the environment (Xu & Wu, 2017).

Environmental flows values were extracted from the Basin Futures tool.
Livestock water demands was based on the consideration of the population in 2000, a daily per capita water consumption of 50L, and its estimated growth rate of 29% in 25 years (ICID, 2005).

The Blue Water Scarcity index including livestock water requirements and environmental water requirements is considered as a proxy for evaluating the impact on ecological system health and is calculated as:

$$BWS_{r,t} = \frac{L_{r,t} + Irr_{r,t} + D_{r,t}}{BW_{r,t} - E_{r,t}}$$

Where:

$BWS_{r,t}$ Blue Water Scarcity indice ,

$L_{r,t}$ is livestock mean annual water demands (ML)

$Irr_{r,t}$ is the mean annual irrigation water uses (ML),

$D_{r,t}$ is the mean annual D&I water uses (ML),

$BW_{r,t}$ is the mean annual blue water availability (ML), including storages and D&I water return,

$E_{r,t}$ is the mean annual environmental flow (ML)

Evaluation of the level of stress is based on the following categories (Xu & Wu, 2017), unacceptable values being achieved for high water stress levels:

Category	Index
Low	<0.1
Moderate	0.1-0.2
Medium	0.2-0.4
High	>0.4

1.2.4. Population health's objective

Basin Futures includes some indications of the nutrition value for crops but do not specifically address issues of population health based on the provision of nutritious food.

We assume that the Green Blue Water (GBW) scarcity indicator (Kummu et al., 2014) could be used as a proxy for population health by evaluating the satisfaction of individuals diet relative to a fixed reference diet. We use a fixed diet and catchment-scale water availability with accounting for climate variability, inspired from Xu & Wu (2017).

Blue water availability (m^3/year) is defined as the amount of available water from the runoff in rivers, the renewable fraction of aquifers and reservoirs, reduced by 70% to account for ecological flow requirements of 30% (Xu & Wu, 2017), and given by:

$$BW\_sc_{r,t,y} = 0.7 \times \sum_{m} U_{r,t,m} + RO_{r,t,m} + T_{r,t,m} + S\_sc_{r,t,m} + D_{r,t,m} + OFS_{r,t,m}$$

Where:

$BW\_sc_{r,t,y}$ is the annual blue water availability (m^3/year),

$U_{r,t,m}$ is the mean monthly upstream inflow in year y (m^3/month),

$RO_{r,t,m}$ is the mean monthly runoff (m^3/month),

$T_{r,t,m}$ is the mean monthly water transfers (m^3/month),

$S\_sc_{r,t,m}$ is the mean monthly storage volume (m^3/month),

$OFS_{r,t,m}$ is the mean monthly volume in on-farm water storages (m^3/month),

$D_{r,t,m}$ is the D&I water return (m^3/month).

Cropland green water availability (m^3/year) is the sum of rainfed and irrigated actual crop evapotranspiration (ET_a), estimated in their respective crop models (sections 2.1.1 and 2.1.2). To account for values in m^3/year rather than mm/year, the respective land areas for rainfed and irrigated crops, according to irrigation development scenarios:

$$ETactual\_rain\_sc_{r,t} = \sum_{c}\sum_{y} ETactual\_rain_{c,r,t,y} \times A\_rain\_sc_{c,r,t} \times 10$$

And

$$ETactual\_irr\_sc_{r,t} = \sum_{c}\sum_{y} ETactual\_irr_{c,r,t,y} \times A\_irr\_sc_{c,r,t} \times 10$$

Where:

$ETactual\_rain\_sc_{r,t}$ and $ETactual\_irr\_sc_{r,t}$ are rainfed and irrigated crops mean annual evapotranspiration respectively (m^3/year),

$ETactual\_rain_{c,r,t,y}$ and $ETactual\_irr_{c,r,t,y}$ are the mean annual evapotranspiration (mm) of rainfed and irrigated crops c, in a dedicated year y, respectively,

$A\_rain\_sc_{c,r,t}$ and $A\_irr\_sc_{c,r,t}$ are the mean annual planting area (ha) for each crop considered, according to their planting time, for rainfed and irrigated crops, respectively,

10 is a conversion factor from mm.ha to m.m^2

The total green water availability from rainfed and irrigated crops is given by:

$$GWcrop\_sc_{r,t,y} = ETactual\_rain\_sc_{r,t} + ETactual\_irr\_sc_{r,t} - Irr_{r,t}/1000$$

Where:

$GWcrop\_sc_{r,t,y}$ is the annual cropland green water availability (m^3/year),

$Irr_{r,t}$ is the mean annual irrigation water uses (ML)

1000 is a conversion factor from ML to m^3

To account for an animal diet mostly based on fish inputs than livestock, we assume that the relative changes in the occurrence in peak flood events (Q10) with current values could impact the reference value of 251 m^3/capita/year, for the contribution of animal inputs to the reference diet (Xu & Wu, 2017), accordingly.

$$ETgrass_{r,t} = 251 \times \left(1 + \left(\frac{fQ10\_sc_{r,t}}{fQ10\_sc_{r,current}} - 1\right)\right)$$

Where:

$ETgrass_{r,t,y}$ is the contribution of animal inputs to the reference diet (m^3/capita/year),

$fQ10\_sc_{r,t}$ is the frequency of occurrence of peak flood events in a period *t,*

$fQ10\_sc_{r,current}$ is the frequency of occurrence of peak flood events for current time.

251 is the reference value for animal inputs and contribution to the reference diet (m^3/capita/year)

The total green blue water availability is the sum of blue water availability and green water availability as:

$$GBW\_sc_{r,t} = \frac{GW\_crop\_sc_{r,t} + BW\_sc_{r,t}}{Pop_{r,t}} + ETgrass_{r,t}$$

Where:

$GBW\_sc_{r,t}$ is the mean annual Green Blue Water availability per capita (m^3)

$Pop_{r,t}$ is the total population in reach *r* for timestep *t*.

The Green Blue Water Scarcity index per capita is given by:

$$GBWS\_sc_t = \sum\nolimits_r \frac{GBW\_sc_{r,t}}{1300}$$

Where:

$GWBS\_sc_{r,t}$ is the scarcity index for population diet, 1300 is the fixed reference diet (m^3/capita/year) (Xu & Wu, 2017)

Values for the whole basin are given by averaging reaches 1 to 7. For the two states, values for Jharkhand are given by averaging reaches 1 to 4, and, for the state of Odissa, reaches 5 to 7.

For $GBWS\_sc_t \geq 1$, the population diet is acceptable.
Conversely, for $GBWS\_sc_t < 1$, the population diet is unacceptable, and its health is expected to be impacted.

1.2.5. Flood security's objective

Flood security is not directly considered in Basin Futures but could be inferred from the flow duration curve provided in the tool. The overbank flow or bankfull discharge is the amount of discharge in a basin that could not be carried out by a stream channel without overflowing. Based on Marchand et al (2021) modeling flood for Jenapur, overbank flows occur for flows comprised between Q1 (1/100 return-period) and Q4 (1/25 return-period). We consider a flood security risk for flows above Q2 (i.e., equaled or exceeded 2% of the time).

The Flood Hazard Index (FHI) is used to estimate the probability for a stream flow to be above the bankfull discharge over a timeperiod (Cheng, 2013). It is assumed that unacceptable FHI values, and increased flood security risk for the population, occur for a relative increase in FHI values compared to current ones.

FHI values for the whole basin is given by:

$$FHI\_sc_t = \frac{1}{7} \times \sum_r \frac{n_{month\ Q\_sc>Qbankfull\_sc,r,t}}{n_{month,r,t}}$$

Where:
FHI_sc_t is the mean FHI value for a period *t*,
$n_{month\ Q\_sc>Qbankfull\_sc,r,t}$ is the number of months with a discharge over the bankfull one
$n_{month,r,t}$ is the total number of months in a time period.

FHI values for the State of Jharkhand are given by:

$$FHI\_sc_{Jharkhand,r,t} = \frac{1}{4} \times \sum\nolimits_{r=1}^{4} \frac{n_{month\ Q\_sc>Qbankfull\_sc,r,t}}{n_{month,r,t}}$$

Where:

$FHI\_sc_{Jharkhand,r,t}$ is the mean FHI value for the State of Jharkhand.

FHI values for the State of Odissa is given by:

$$FHI\_sc_{Odissa,r,t} = \frac{1}{3} \times \sum\nolimits_{r=5}^{7} \frac{n_{month\ Q\_sc>Qbankfull\_sc,r,t}}{n_{month,r,t}}$$

Where:

$FHI\_sc_{Odissa,r,t}$ is the mean FHI value for the State of Odissa.

2. Parameters used to set the scenarios for the Brahmani River Basin in Basin Futures

2.1. Irrigated and rainfed crops' water demands and yields

2.1.1. Common datasets to estimate crop water demands, crop yields and crop incomes

	Rice	**Pulses**	**Sugarcane**
ET crop coefficient K_c[1]	1.2	1.25	1.1
Planting months[2]	June	June and October	June
Growing time (days) [2]	120	110	365
Moisture stress response factor K_y [2]	1	1	1
Maximum yield $Y_{max,c}$ (t/ha) [2]	10	7	212
Price $P_{c,r,t}$ in 2000 USD$/t [2]	$432.30	$284	$300

2.1.2. Irrigated planting area, cropping intensity, and land suitability

Values for irrigated land area are based on the consideration major and medium storages and associated CCA (ICID, 2005; Pollino et al., 2016), and irrigation development pace (ICID, 2005). Land suitability datasets were provided by the Basin Futures tool. The available land area was estimated after considering urban growth and land encroachment, and no changes in grassland areas and in existing terrestrial protected areas in the basin.

2.1.2.1. Culturable Command Areas (CCA)

CCA are based on major and medium irrigation schemes in the basin coverage (ha) and vary according to the irrigation scenario considered. Values are derived from ICID (2005) and Pollino et al. (2016).

[1] Doorenbos & Pruitt, 1977

[2] Basin Futures datasets

For bau1 and irr1:

Reach	1961-2005	2006-2010	2011-2020	2021-2030	2031-2040	2041-2050
1	2441	2441	5431	5431	5431	5431
2	9958	9958	16218	16218	16218	16218
3	0	0	14710	14710	14710	14710
4	5050	5050	16648	16648	16648	16648
5	30000	30000	76995	76995	76995	76995
6	17512	17512	18693	18693	18693	18693
7	361031	361031	617313	617313	617313	617313

For bau2 and irr2:

Reach	1961-2005	2006-2010	2011-2020	2021-2030	2031-2040	2041-2050
1	2441	2441	5431	5431	5431	5431
2	9958	9958	16218	16218	16218	16218
3	0	0	17710	17710	17710	17710
4	5050	5050	16648	16648	16648	16648
5	30000	30000	131813	131813	131813	131813
6	17512	17512	47113	47113	47113	47113
7	361031	361031	714368	714368	714368	714368

2.1.2.2. bau1 scenario

2.1.2.2.1. Planting area and cropping intensity

1961-2005	Rice		Rice		Pulses		Pulses		Sugarcane	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	J	1823	O	203	J	373	O	41		
2	J	7439	O	827	J	1524	O	169		
3	J	0	O	0	J	0	O	0		
4	J	2502	O	278	J	513	O	57	J	1700
5	J	22410	O	2490	J	4590	O	510		
6	J	13082	O	1454	J	2679	O	298		
7	J	174757	O	2269	J	4421	O	6892		

J = June and O = October

2006-2010	Rice		Rice		Pulses		Pulses		Sugarcane	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	J	1823	O	203	J	373	O	41		
2	J	7439	O	827	J	1524	O	169		
3	J	0	O	0	J	0	O	0		
4	J	2502	O	278	J	513	O	57	J	1700
5	J	22410	O	2490	J	4590	O	510		

6	J	13082	O	1454	J	2679	O	298		
7	J	302224	O	8701	J	33113	O	10981	J	6012

J = June and O = October

2011-2020	Rice		Rice		Pulses		Pulses		Sugarcane	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	J	2301	O	267	J	557	O	52		0
2	J	9386	O	1088	J	2274	O	211		0
3	J	3060	O	340	J	627	O	70		0
4	J	3157	O	366	J	765	O	71	J	4157
5	J	28275	O	3278	J	6850	O	636		0
6	J	13446	O	1574	J	3372	O	301		0
7	J	381326	O	11455	J	49419	O	13687	J	14699

J = June and O = October

2021-2030	Rice		Rice		Pulses		Pulses		Sugarcane	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	J	2778	O	331	J	741	O	62		0
2	J	11333	O	1350	J	3024	O	253		0
3	J	3694	O	422	J	833	O	83		0

4	J	3812	O	454	J	1017	O	85	J	6613
5	J	34141	O	4066	J	9111	O	761		0
6	J	12993	O	1592	J	3821	O	287		0
7	J	463671	O	14570	J	66390	O	16466	J	23387

J = June and O = October

2031-2040	Rice		Rice		Pulses		Pulses		Sugarcane	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	J	3354	O	410	J	986	O	74		0
2	J	11096	O	1387	J	3492	O	244		0
3	J	7048	O	811	J	1638	O	159		0
4	J	4233	O	522	J	1277	O	93	J	10521
5	J	44506	O	8327	J	15400	O	4195		0
6	J	12993	O	1592	J	3821	O	287		0
7	J	477870	O	16147	J	69298	O	16789	J	37209

J = June and O = October

2041-2050	Rice		Rice		Pulses		Pulses		Sugarcane	

Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	J	3656	O	465	J	1230	O	80		0
2	J	11096	O	1387	J	3492	O	244		0
3	J	8905	O	1049	J	2260	O	199		0
4	J	4233	O	522	J	1277	O	93	J	10521
5	J	47917	O	8706	J	16099	O	4272		0
6	J	12993	O	1592	J	3821	O	287		0
7	J	477870	O	16147	J	69298	O	16789	J	37209

J = June and O = October

2.1.2.2.2. Planted areas (ha) with considering land suitability

Reaches	Suitability	1	2	3	4	5	6	7
2000	highly	0	0	0	0	0	0	0
	moderate	2441	9958	0	5050	30000	17512.39	188338.6
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2010	highly	0	0	0	0	0	0	0
	moderate	2441	9958	0	5050	30000	17512.39	361030.6
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2020	highly	0	0	4096	0	0	0	0
	moderate	3176.531	12958.58	0	8515.969	39039.71	18693.29	470586.9
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2030	highly	0	0	5032.998	0	0	0	0
	moderate	3912.062	15959.16	0	11981.94	48079.41	18693.18	584483.2
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2040	highly	0	0	9656.267	0	0	0	0
	moderate	4824.722	16218.33	0	16647.82	72428.31	18693.18	617313
	marginal	0	0	0	0	0	0	0

	bad	0	0	0	0	0	0	0
2050	highly	0	0	12413.32	0	0	0	0
	moderate	5431.179	16218.33	0	16647.82	76994.31	18693.18	617313
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0

2.1.2.3. bau2 scenario

2.1.2.3.1. Planting area and cropping intensity

1961-2005	Rice		Rice		Pulses		Pulses		Sugarcane	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	J	1823	O	203	J	373	O	41		
2	J	7439	O	827	J	1524	O	169		
3	J	0	O	0	J	0	O	0		
4	J	2502	O	278	J	513	O	57	J	1700
5	J	22410	O	2490	J	4590	O	510		
6	J	13082	O	1454	J	2679	O	298		
7	J	174757	O	2269	J	4421	O	6892		

2006-2010	Rice		Rice		Pulses		Pulses		Sugarcane	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	J	1823	O	203	J	373	O	41		
2	J	7439	O	827	J	1524	O	169		
3	J	0	O	0	J	0	O	0		
4	J	2502	O	278	J	513	O	57	J	1700
5	J	22410	O	2490	J	4590	O	510		
6	J	13082	O	1454	J	2679	O	298		

7	J	302224	O	8701	J	33113	O	10981	J	6012

2011-2020	Rice		Rice		Pulses		Pulses		Sugarcane	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	J	2301	O	267	J	557	O	52		0
2	J	9386	O	1088	J	2274	O	211		0
3	J	0	O	0	J	0	O	0		0
4	J	3157	O	366	J	765	O	71	J	4157
5	J	28275	O	3278	J	6850	O	636		0
6	J	16506	O	1914	J	3999	O	371		0
7	J	381326	O	11455	J	49419	O	13687	J	14699

2021-2030	Rice		Rice		Pulses		Pulses		Sugarcane	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	J	2778	O	331	J	741	O	62		0
2	J	11333	O	1350	J	3024	O	253		0
3	J	0	O	0	J	0	O	0		0
4	J	3812	O	454	J	1017	O	85	J	6613
5	J	34141	O	4066	J	9111	O	761		0
6	J	19930	O	2374	J	5318	O	444		0
7	J	460429	O	14209	J	65726	O	16392	J	23387

2031-2040	Rice		Rice		Pulses		Pulses		Sugarcane	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	J	3354	O	410	J	986	O	74		0
2	J	11096	O	1387	J	3492	O	244		0
3	J	2957	O	329	J	606	O	67		0
4	J	4233	O	522	J	1277	O	93	J	10521
5	J	41223	O	5044	J	12117	O	912		0
6	J	26643	O	3231	J	7601	O	591		0
7	J	553361	O	17339	J	86885	O	19573	J	37209

2041-2050	Rice		Rice		Pulses		Pulses		Sugarcane	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	J	4057	O	451	J	831	O	92		0
2	J	12115	O	1346	J	2481	O	276		0
3	J	12115	O	1346	J	2481	O	276		0
4	J	4577	O	509	J	937	O	104	J	10521
5	J	49775	O	6257	J	16115	O	1092		0
6	J	32170	O	4008	J	10110	O	708		0
7	J	505838	O	56204	J	103605	O	11512	J	30205

2.1.2.3.2. Planted areas (ha) with considering land suitability

Reaches	**Suitability**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
2000	highly	0	0	0	0	0	0	0
	moderate	2441	9958	0	5050	30000	17512.39	188338.6
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2010	highly	0	0	0	0	0	0	0
	moderate	2441	9958	0	5050	30000	17512.39	361030.6
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2020	highly	0	0	0	0	0	0	0
	moderate	3176.531	12958.58	0	8515.969	39039.71	22789.29	470586.9
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2030	highly	0	0	0	0	0	0	0
	moderate	3912.062	15959.16	0	11981.94	48079.41	28066.18	580143.2
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2040	highly	0	0	3959	0	0	0	0
	moderate	4824.722	16218.33	0	16647.82	59296.05	38066.85	714367.5
	marginal	0	0	0	0	0	0	0

	bad	0	0	0	0	0	0	0
2050	highly	0	0	16218	0	0	0	0
	moderate	5431	16218	0	16648	73238.58	46995.66	707363.9
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0

2.1.2.4. irr1 scenario

2.1.2.4.1. Planting area and cropping intensity

1961-2005	Rice		Rice		Pulses		Pulses		Sugarcane	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	J	1823	O	203	J	373	O	41		
2	J	7439	O	827	J	1524	O	169		
3	J	0	O	0	J	0	O	0		
4	J	2502	O	278	J	513	O	57	J	1700
5	J	22410	O	2490	J	4590	O	510		
6	J	13082	O	1454	J	2679	O	298		
7	J	174757	O	2269	J	4421	O	6892		

2006-2010	Rice		Rice		Pulses		Pulses		Sugarcane	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	J	1823	O	203	J	373	O	41		
2	J	7439	O	827	J	1524	O	169		
3	J	0	O	0	J	0	O	0		
4	J	2502	O	278	J	513	O	57	J	1700
5	J	22410	O	2490	J	4590	O	510		
6	J	13082	O	1454	J	2679	O	298		

7	J	309412	O	7128	J	32954	O	11537	J	13280

2011-2020	Rice		Rice		Pulses		Pulses		Sugarcane	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	J	2381	O	275	J	568	O	54		0
2	J	9713	O	827	J	2319	O	219		0
3	J	3215	O	357	J	659	O	73		0
4	J	3268	O	278	J	780	O	74	J	2830
5	J	29262	O	2490	J	6985	O	659		0
6	J	13867	O	1096	J	3419	O	311		0
7	J	404020	O	9145	J	50151	O	14898	J	22110

2021-2030	Rice		Rice		Pulses		Pulses		Sugarcane	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	J	2939	O	348	J	763	O	66		0
2	J	11841	O	1028	J	3084	O	265		0
3	J	4114	O	468	J	914	O	93		0

4	J	4033	O	351	J	1048	O	90	J	3961
5	J	31470	O	3497	J	6446	O	716		0
6	J	13964	O	1552	J	2860	O	318		0
7	J	507667	O	12562	J	69199	O	18464	J	30939

2031-2040	Rice		Rice		Pulses		Pulses		Sugarcane	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	J	3627	O	439	J	1025	O	80		0
2	J	11506	O	954	J	3505	O	254		0
3	J	8186	O	936	J	1864	O	185		0
4	J	4977	O	444	J	1407	O	110	J	5542
5	J	31470	O	3497	J	6446	O	716		0
6	J	13964	O	1552	J	2860	O	318		0
7	J	451202	O	50134	J	92415	O	10268	J	43295

2041-2050	Rice		Rice		Pulses		Pulses		Sugarcane	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	J	3673	O	466	J	1212	O	80		0
2	J	12115	O	1346	J	2481	O	276		0

3	J	10906	O	1273	J	2668	O	245		0
4	J	6143	O	561	J	1889	O	135	J	7756
5	J	31470	O	3497	J	6446	O	716		0
6	J	13964	O	1552	J	2860	O	318		0
7	J	438286	O	48698	J	89769	O	9974	J	60586

2.1.2.4.2. Planted areas (ha) with considering land suitability

Reaches	Suitability	1	2	3	4	5	6	7
2000	highly	0	0	0	0	0	0	0
	moderate	2441	9958	0	5050	30000	17512.39	188338.6
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2010	highly	0	0	0	0	0	0	0
	moderate	2441	9958	0	5050	30000	17512.39	374310.6
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2020	highly	0	0	4304	0	0	0	0
	moderate	3278.109	13076.89	0	7229.541	39396.13	18693.34	500323.8
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2030	highly	0	0	5589.399	0	0	0	0
	moderate	4115.218	16217.76	0	9482.417	42128.42	18693.34	638831.4
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2040	highly	0	0	11171.71	0	0	0	0
	moderate	5171.586	16217.9	0	12480.67	42128.42	18693.34	647313.7
	marginal	0	0	0	0	0	0	0

	bad	0	0	0	0	0	0	0
2050	highly	0	0	15091.61	0	0	0	0
	moderate	5431.367	16218	0	16483.93	42128.42	18693.34	647313.7
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0

2.1.2.5. irr2 scenario

2.1.2.5.1. Planting area and cropping intensity

1961-2005	Rice		Rice		Pulses		Pulses		Sugarcane	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	J	1823	O	203	J	373	O	41		
2	J	7439	O	827	J	1524	O	169		
3	J	0	O	0	J	0	O	0		
4	J	2502	O	278	J	513	O	57	J	1700
5	J	22410	O	2490	J	4590	O	510		
6	J	13082	O	1454	J	2679	O	298		
7	J	174757	O	2269	J	4421	O	6892		

2006-2010	Rice		Rice		Pulses		Pulses		Sugarcane	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	J	1823	O	203	J	373	O	41		
2	J	7439	O	827	J	1524	O	169		
3	J	0	O	0	J	0	O	0		
4	J	2502	O	278	J	513	O	57	J	1700
5	J	22410	O	2490	J	4590	O	510		
6	J	13082	O	1454	J	2679	O	298		

7	J	309412	O	7128	J	32954	O	11537	J	13280

2011-2020	Rice		Rice		Pulses		Pulses		Sugarcane	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	J	2727	O	214	J	411	O	42		0
2	J	11125	O	872	J	1678	O	171		0
3	J	0	O	0	J	0	O	0		0
4	J	3743	O	293	J	565	O	58	J	2272
5	J	33515	O	2627	J	5056	O	516		0
6	J	19564	O	1534	J	2951	O	301		0
7	J	462736	O	7520	J	36299	O	11667	J	17750

2021-2030	Rice		Rice		Pulses		Pulses		Sugarcane	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	J	3366	O	270	J	552	O	51		0
2	J	12925	O	1013	J	2089	O	192		0
3	J	805	O	89	J	165	O	18		0
4	J	4619	O	371	J	758	O	71	J	3180
5	J	41363	O	3320	J	6790	O	632		0

6	J	24146	O	1938	J	3963	O	369		0
7	J	571094	O	9504	J	48746	O	14299	J	24839

2031-2040	Rice		Rice		Pulses		Pulses		Sugarcane	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	J	4154	O	341	J	742	O	63		0
2	J	12924	O	943	J	2185	O	166		0
3	J	4021	O	449	J	842	O	91		0
4	J	5700	O	469	J	1018	O	87	J	4450
5	J	51049	O	4196	J	9118	O	775		0
6	J	29800	O	2449	J	5322	O	452		0
7	J	507668	O	56408	J	103980	O	11553	J	34759

2041-2050	Rice		Rice		Pulses		Pulses		Sugarcane	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	J	4057	O	451	J	831	O	92		0
2	J	12115	O	1346	J	2481	O	276		0
3	J	8893	O	1005	J	1935	O	201		0
4	J	7035	O	592	J	1367	O	106	J	6227

5	J	63347	O	5340	J	12315	O	957		0
6	J	35194	O	3910	J	7208	O	801		0
7	J	497003	O	55223	J	101796	O	11311	J	41636

2.1.2.5.2. Planted areas (ha) with considering land suitability

Reaches	**Suitability**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
2000	highly	0	0	0	0	0	0	0
	moderate	2441	9958	0	5050	30000	17512.39	188338.6
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2010	highly	0	0	0	0	0	0	0
	moderate	2441	9958	0	5050	30000	17512.39	374310.6
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2020	highly	0	0	0	0	0	0	0
	moderate	3394.1	13846.15	0	6930.301	41713.64	24350.19	535972.6
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2030	highly	0	0	1077	0	0	0	0
	moderate	4239.582	16218.27	0	8998.083	52104.65	30415.9	668481.3
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2040	highly	0	0	5403.603	0	0	0	0
	moderate	5299.974	16217.51	0	11723.2	65136.92	38023.44	714367.9
	marginal	0	0	0	0	0	0	0

	bad	0	0	0	0	0	0	0
2050	highly	0	0	12033.97	0	0	0	0
	moderate	5431	16218	0	15327.25	81959.74	47113.19	706967.9
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0

2.1.3. Rainfed planting area, cropping intensity, and land suitability

Values for rainfed land area are based on ICID (2005). Land suitability datasets were provided by the Basin Futures tool. The estimation of rainfed land area was deduced from the available land area after all other urban and irrigation developments, with considering no changes in grassland areas and in existing terrestrial protected areas in the basin.

2.1.3.1. bau1 scenario

2.1.3.1.1. Planting area and cropping intensity

1961-2005	Rice		Rice		Pulses		Pulses	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	June	687	October	0	June	189	October	21
2	June	1329	October	0	June	365	October	41
3	June	583	October	0	June	160	October	18
4	June	1460	October	0	June	401	October	45
5	June	1247	October	0	June	342	October	38
6	June	534	October	0	June	147	October	16
7	June	1741	October	0	June	478	October	54

2006-2010	Rice		Rice		Pulses		Pulses	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	June	67130	October	0	June	12374	October	1375
2	June	129905	October	0	June	23946	October	2661

3	June	57026	October	0	June	10512	October	1168
4	June	142714	October	0	June	26307	October	2923
5	June	121831	October	0	June	22458	October	2495
6	June	52207	October	0	June	9624	October	1069
7	June	170191	October	0	June	31373	October	3486

2011-2020	Rice		Rice		Pulses		Pulses	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	June	61652	October	0	June	11365	October	1263
2	June	119306	October	0	June	21993	October	2444
3	June	52373	October	0	June	9654	October	1073
4	June	131070	October	0	June	24161	October	2685
5	June	111891	October	0	June	20626	October	2292
6	June	47948	October	0	June	8839	October	982
7	June	156305	October	0	June	28813	October	3201

2021-2030	Rice		Rice		Pulses		Pulses	

Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	June	56175	October	0	June	10355	October	1151
2	June	108707	October	0	June	20039	October	2227
3	June	47721	October	0	June	8797	October	977
4	June	119425	October	0	June	22015	October	2446
5	June	101950	October	0	June	18793	October	2088
6	June	43688	October	0	June	8053	October	895
7	June	142419	October	0	June	26253	October	2917

2031-2040	Rice		Rice		Pulses		Pulses	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	June	51185	October	0	June	9435	October	1048
2	June	99049	October	0	June	18258	October	2029
3	June	43481	October	0	June	8015	October	891
4	June	108816	October	0	June	20059	October	2229
5	June	92893	October	0	June	17124	October	1903
6	June	70663	October	0	June	13026	October	1447
7	June	98910	October	0	June	18233	October	2026

2041-2050	Rice		Rice		Pulses		Pulses	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	June	46637	October	0	June	8597	October	955
2	June	90250	October	0	June	16636	October	1848
3	June	39618	October	0	June	7303	October	811
4	June	99148	October	0	June	18277	October	2031
5	June	84640	October	0	June	15602	October	1734
6	June	79766	October	0	June	14704	October	1634
7	June	74742	October	0	June	13778	October	1531

2.1.3.1.2. Planted areas (ha) with considering land suitability

Reaches	**Suitability**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
2000	highly	0	0	0	0	0	0	0
	moderate	155111.3	265481.1	335564.1	443944.1	440387.3	127444.5	376182.6
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2010	highly	0	0	0	0	0	0	0
	moderate	163877	281319.9	340431.6	460933.7	452461.8	133858.4	216491.7
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2020	highly	0	0	0	0	0	0	0
	moderate	169696.6	289509.3	342570.1	469214.6	450219.4	137239	111288.7
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2030	highly	0	0	0	0	0	0	0
	moderate	175501.8	297177.4	343564.5	476742.5	446268	141612.4	169250.4
	marginal	0	0	0	0	0	0	2339
	bad	0	0	0	0	0	0	0
2040	highly	0	0	0	0	0	0	0
	moderate	180524.2	305758.8	332882.7	480822.3	423670.3	108103.3	114527
	marginal	0	0	0	0	0	0	4642

	Bad	0	0	0	0	0	0	0
2050	Highly	0	0	0	0	0	0	0
	moderate	185293.1	312643.5	326622.4	487100.1	416862.8	95792.73	85408.44
	marginal	0	0	0	0	0	0	4642
	Bad	0	0	0	0	0	0	0

2.1.3.2.bau2 scenario

2.1.3.2.1. Planting area and cropping intensity

1961-2005	Rice		Rice		Pulses		Pulses	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	June	687	October	0	June	189	October	21
2	June	1329	October	0	June	365	October	41
3	June	583	October	0	June	160	October	18
4	June	1460	October	0	June	401	October	45
5	June	1247	October	0	June	342	October	38
6	June	534	October	0	June	147	October	16
7	June	1741	October	0	June	478	October	54

2006-2010	Rice		Rice		Pulses		Pulses	

Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	June	67130	October	0	June	12374	October	1375
2	June	129905	October	0	June	23946	October	2661
3	June	57026	October	0	June	10512	October	1168
4	June	142714	October	0	June	26307	October	2923
5	June	121831	October	0	June	22458	October	2495
6	June	52207	October	0	June	9624	October	1069
7	June	170191	October	0	June	31373	October	3486

2011-2020	Rice		Rice		Pulses		Pulses	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	June	61652	October	0	June	11365	October	1263
2	June	119306	October	0	June	21993	October	2444
3	June	52373	October	0	June	9654	October	1073
4	June	131070	October	0	June	24161	October	2685
5	June	111891	October	0	June	20626	October	2292
6	June	47948	October	0	June	8839	October	982
7	June	156305	October	0	June	28813	October	3201

2021-2030	Rice		Rice		Pulses		Pulses	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	June	56175	October	0	June	10355	October	1151
2	June	108707	October	0	June	20039	October	2227
3	June	47721	October	0	June	8797	October	977
4	June	119425	October	0	June	22015	October	2446
5	June	101950	October	0	June	18793	October	2088
6	June	43688	October	0	June	8053	October	895
7	June	142419	October	0	June	26253	October	2917

2031-2040	Rice		Rice		Pulses		Pulses	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	June	51185	October	0	June	9435	October	1048
2	June	99049	October	0	June	18258	October	2029
3	June	43481	October	0	June	8015	October	891
4	June	108816	October	0	June	20059	October	2229

5	June	204305	October	0	June	37661	October	4185
6	June	39807	October	0	June	7338	October	815
7	June	18355	October	0	June	3384	October	376

2041-2050	Rice		Rice		Pulses		Pulses	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	June	46637	October	0	June	8597	October	955
2	June	90250	October	0	June	16636	October	1848
3	June	39618	October	0	June	7303	October	811
4	June	99148	October	0	June	18277	October	2031
5	June	202879	October	0	June	37398	October	4155
6	June	36270	October	0	June	6686	October	743
7	June	0	October	0	June	0	October	0

2.1.3.2.2. Planted areas (ha) with considering land suitability

Reaches	**Suitability**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
2000	highly	0	0	0	0	0	0	0
	moderate	155111.3	265481.1	335564.1	443944.1	440387.3	127444.5	376182.6
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0

2010	highly	0	0	0	0	0	0	0
	moderate	163877	281319.9	340431.6	460933.7	452461.8	133858.4	216491.7
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2020	highly	0	0	0	0	0	0	0
	moderate	169696.6	289509.3	342570.1	469214.6	450219.4	133143	111288.7
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2030	highly	0	0	0	0	0	0	0
	moderate	175501.8	297177.4	343564.5	476742.5	446268	132239.4	2001.384
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2040	highly	0	0	0	0	0	0	0
	moderate	180524.2	305758.8	338580	480822.3	302571.5	125905.6	17472.5
	marginal	0	0	0	0	0	0	4642
	bad	0	0	0	0	0	0	0
2050	highly	0	0	0	0	0	0	0
	moderate	185293.3	312643.8	322817.7	487100	278162.6	119895.3	0
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0

2.1.3.3. irr1 scenario

2.1.3.3.1. Planting area and cropping intensity

1961-2005	Rice		Rice		Pulses		Pulses	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	June	687	October	0	June	189	October	21
2	June	1329	October	0	June	365	October	41
3	June	583	October	0	June	160	October	18
4	June	1460	October	0	June	401	October	45
5	June	1247	October	0	June	342	October	38
6	June	534	October	0	June	147	October	16
7	June	1741	October	0	June	478	October	54

2006-2010	Rice		Rice		Pulses		Pulses	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	June	68601	October	0	June	12646	October	1405
2	June	132752	October	0	June	24471	October	2719
3	June	58276	October	0	June	10742	October	1194
4	June	145841	October	0	June	26884	October	2987
5	June	124501	October	0	June	22950	October	2550

6	June	53351	October	0	June	9835	October	1093
7	June	173921	October	0	June	32060	October	3562

2011-2020	Rice		Rice		Pulses		Pulses	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	June	64227	October	0	June	11839	October	1315
2	June	124288	October	0	June	22911	October	2546
3	June	54560	October	0	June	10058	October	1118
4	June	136542	October	0	June	25170	October	2797
5	June	116563	October	0	June	21487	October	2387
6	June	49950	October	0	June	9208	October	1023
7	June	162832	October	0	June	30016	October	3335

2021-2030	Rice		Rice		Pulses		Pulses	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	June	59853	October	0	June	11033	October	1226
2	June	115823	October	0	June	21351	October	2372
3	June	50845	October	0	June	9373	October	1041
4	June	127244	October	0	June	23456	October	2606

5	June	108625	October	0	June	20024	October	2225
6	June	99069	October	0	June	18262	October	2029
7	June	99222	October	0	June	18290	October	2032

2031-2040	Rice		Rice		Pulses		Pulses	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	June	55777	October	0	June	10282	October	1142
2	June	107936	October	0	June	19897	October	2211
3	June	47382	October	0	June	8734	October	970
4	June	118578	October	0	June	21858	October	2429
5	June	101227	October	0	June	18660	October	2073
6	June	110777	October	0	June	20420	October	2269
7	June	74010	October	0	June	13643	October	1516

2041-2050	Rice		Rice		Pulses		Pulses	
Reaches	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	June	51978	October	0	June	9582	October	1065
2	June	100585	October	0	June	18542	October	2060

3	June	44155	October	0	June	8139	October	904
4	June	110503	October	0	June	20370	October	2263
5	June	94333	October	0	June	17389	October	1932
6	June	122362	October	0	June	22556	October	2506
7	June	49841	October	0	June	9188	October	1021

2.1.3.3.2. Planted areas (ha) with considering land suitability

Reaches	**Suitability**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
2000	highly	0	0	0	0	0	0	0
	moderate	155111.3	265481.1	335564.1	443944.1	440387.3	127444.5	376182.6
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2010	highly	0	0	0	0	0	0	0
	moderate	162104.6	277890.1	338926	457165.8	449245.2	132480	198718.3
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2020	highly	0	0	0	0	0	0	0
	moderate	166493.4	283389	339935.3	463907.2	444234	134826.8	73688.45
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2030	highly	0	0	0	0	0	0	0
	moderate	170867.7	288344.4	334211.1	469822.1	444177.5	74888.31	114902.3
	marginal	0	0	0	0	0	0	4642
	bad	0	0	0	0	0	0	0
2040	highly	0	0	0	0	0	0	0
	moderate	174644.6	295052.6	326667.2	473227.1	443928.9	59772.28	84526.33
	marginal	0	0	0	0	0	0	4642

	bad	0	0	0	0	0	0	0
2050	highly	0	0	0	0	0	0	0
	moderate	178858	300191.3	318477.7	473583.7	440050.2	44473.08	55407.79
	marginal	0	0	0	0	0	0	4642
	bad	0	0	0	0	0	0	0

2.1.3.4. irr2 scenario

2.1.3.4.1. Planting area and cropping intensity

2000	Rice		Rice		Pulses		Pulses	
	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	June	687	October	0	June	189	October	21
2	June	1329	October	0	June	365	October	41
3	June	583	October	0	June	160	October	18
4	June	1460	October	0	June	401	October	45
5	June	1247	October	0	June	342	October	38
6	June	534	October	0	June	147	October	16
7	June	1741	October	0	June	478	October	54

2010	Rice		Rice		Pulses		Pulses	
	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	June	68601	October	0	June	12646	October	1405
2	June	132752	October	0	June	24471	October	2719
3	June	58276	October	0	June	10742	October	1194
4	June	145841	October	0	June	26884	October	2987

5	June	124501	October	0	June	22950	October	2550
6	June	53351	October	0	June	9835	October	1093
7	June	173921	October	0	June	32060	October	3562

2020	Rice		Rice		Pulses		Pulses	
	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	June	64227	October	0	June	11839	October	1315
2	June	124288	October	0	June	22911	October	2546
3	June	54560	October	0	June	10058	October	1118
4	June	136542	October	0	June	25170	October	2797
5	June	116563	October	0	June	21487	October	2387
6	June	49950	October	0	June	9208	October	1023
7	June	162832	October	0	June	30016	October	3335

2030	Rice		Rice		Pulses		Pulses	
	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	June	59853	October	0	June	11033	October	1226

2	June	115823	October	0	June	21351	October	2372
3	June	50845	October	0	June	9373	October	1041
4	June	127244	October	0	June	23456	October	2606
5	June	108625	October	0	June	20024	October	2225
6	June	123678	October	0	June	22799	October	2533
7	June	74612	October	0	June	13754	October	1528

2040	Rice		Rice		Pulses		Pulses	
	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	June	55777	October	0	June	10282	October	1142
2	June	107936	October	0	June	19897	October	2211
3	June	47382	October	0	June	8734	October	970
4	June	118578	October	0	June	21858	October	2429
5	June	224281	October	0	June	41343	October	4594
6	June	43378	October	0	June	7996	October	888
7	June	18355	October	0	June	3383	October	376

2050	Rice		Rice		Pulses		Pulses	

	Time	area (ha)	Time	area (ha)	Time	area (ha)	Time	area (ha)
1	June	51978	October	0	June	9582	October	1065
2	June	100585	October	0	June	18542	October	2060
3	June	44155	October	0	June	8139	October	904
4	June	110503	October	0	June	20370	October	2263
5	June	225784	October	0	June	41620	October	4624
6	June	40424	October	0	June	7452	October	828
7	June	328	October	0	June	61	October	7

2.1.3.4.2. Planted areas (ha) with considering land suitability

Reaches	**Suitability**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
2000	highly	0	0	0	0	0	0	0
	moderate	155111.3	265481.1	335564.1	443944.1	440387.3	127444.5	376182.6
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2010	highly	0	0	0	0	0	0	0
	moderate	162104.6	277890.1	338926	457165.8	449245.2	132480	198718.3
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2020	highly	0	0	0	0	0	0	0
	moderate	166377.4	282619.7	339935.3	464206.4	441916.5	129170	38039.59
	marginal	0	0	0	0	0	0	0
	bad	0	0	0	0	0	0	0
2030	highly	0	0	0	0	0	0	0
	moderate	170743.3	288343.9	338723.5	470306.5	434201.3	33515.75	85252.32
	marginal	0	0	0	0	0	0	4642
	bad	0	0	0	0	0	0	0
2040	highly	0	0	0	0	0	0	0
	moderate	174516.2	295053	332435.3	473984.5	272662.5	121646.2	17472.12
	marginal	0	0	0	0	0	0	4642

	bad	0	0	0	0	0	0	0
2050	highly	0	0	0	0	0	0	0
	moderate	178858.4	300191.3	321535.3	474740.4	241844.9	114773.2	0
	marginal	0	0	0	0	0	0	396
	bad	0	0	0	0	0	0	0

2.2. Fisheries

Fish harvesting factor based on reservoir area in India (Sugunan, 1995) and local market price for native local fish (identified based on Basin Futures datasets).

	Values
Fish harvesting (kg/ha/year)	29.5
Price for Wallago attu (taka) / (USD$ in 2000)[3]	700 / 8.4

Waterbodies area (km^2) based on Basin Futures land uses for 2000

Reaches	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Waterbodies area in 2000 (km^2)	20	121	29	232	1126	13	636

In-stream reservoirs area (km^2) based on Pollino et al. (2016) and web-based research about the dams listed in ICID (2005) for:

bau1 and irr1 scenarios:

Reach	1961-2005	2006-2010	2011-2020	2021-2030	2031-2040	2041-2050
1	3	3	3	3	3	3
2	17	17	17	17	17	17
3	0	0	2	2	2	2
4	31	31	38	38	38	38
5	311	311	311	311	311	311
6	12	12	12	12	12	12
7	17	17	17	17	17	17

bau2 and irr2 scenarios:

Reach	1961-2005	2006-2010	2011-2020	2021-2030	2031-2040	2041-2050
1	3	3	3	3	3	3
2	17	17	17	17	17	17
3	0	0	76	76	76	76
4	31	31	38	38	38	38
5	311	311	607	607	607	607

[3] Deb & Dey (2020)

6	12	12	288	288	288	288
7	17	17	58	58	58	58

3. Problem framing for the Brahmani River Basin illustrative case

3.1. Definition of the assumptions, constraints, and conditions of success for the BRB system's objectives.

Rural incomes objective	
Assumptions	Rural incomes rely on crop (rainfed and irrigated) and fisheries production.
Constraints	Irrigated land could not expand beyond the Cultivable Command Area (CCA). Rainfed land could not expand beyond the remaining arable land area after urban and irrigation developments.
Conditions of success	Rural net incomes per capita are equal to or above current (2000) incomes.
Urban incomes objective	
Assumptions	Urban incomes are based on the consideration of: urban density as a proxy for urban poverty. hydropower production as a proxy for energy security for industrial production and revenues.
Constraints	Urban area growth is increasing continuously by 33% every decade
Conditions of success	Urban density is under 7963 inhabitants/km^2, represented by ratio urban density threshold exceedance ratio: (density-7693) / 7693 < 0 Mean annual hydropower generation is greater than or equal to current (2000) estimates, represented by hydropower increase ratio: (new – 2000 estimate) / (2000 estimate) ≥ 0
Population health objective	
Assumptions	satisfaction of the reference diet (1300 m^3/capita/year) based on the availability of green water and blue water is a proxy for population health to account for dietary requirements from fish consumption, green water values associated to animal feeding were adjusted to account for changes in fisheries production associated with changes in the occurrence of peak flood events
Constraints	Grassland area remains unchanged over time to account for livestock food and water requirements
Conditions of success	Reference diet is satisfied, represented by diet ratio actual/reference ≥ 1
Ecological systems health objective	

Assumptions	Surface water extractions include those from both surface water and groundwater uses Consumptive water use includes domestic, industrial (D&I), irrigation and livestock uses Freshwater availability includes, in addition to surface water and in-stream storage volume, water transfers, the volume of on-farm water storage and D&I water return. D&I water return only assumes freshwater return and is defined as the proportion of water extracted not consumed (80% of water demand) and treated.
Constraints	Water availability is the difference between the amount of renewable freshwater resources and the volume of water allocated to aquatic systems.
Conditions of success	Consumptive use is kept to less than 40% of water availability, considering needs of healthy aquatic systems
Flood security objective	
Assumptions	Flood security is based on the reduction of the frequency of peak flood events exceeded or reached 2% of the time (Q2)
Constraints	None specified
Conditions of success	Flood security is achieved for a frequency of Q2 events under or equal to 2000 values.

3.2.Actions for the BRB and associated characteristics.

Action	Description	Conditions of implementation
Irrigation growth	Business as usual: growth of 165% from 2000 to 2025	Irrigated land expansions are limited by the culturable land area (CCA) and by soil availability of high and moderate suitability.
	Irrigation development: growth of 208% from 2000 to 2025	
Proposed major and medium dams	The implementation of the proposed dams is expected to increase the CCA by 24%.	A lead time of 20 years is necessary from the design to the full implementation of the projects. In situations of emergent events such as a global pandemic or global financial crisis, projects are delayed for 10 years.
Irrigation policy supporting the adoption of (new) water efficient technologies for field applications	Irrigation water efficiency shift from 50% efficiency to 80%.	No lead times or delay associated with emergent global events
Domestic and industrial (D&I) effluent management policy	20% of D&I effluent treatment before return to surface water	A lead time of 10 years for implementation of wastewater treatment infrastructures
	50% of D&I effluent treatment before return to surface water	A lead time of 10 years for implementation of wastewater treatment infrastructures Delay of 10 years in case of emergent global events
Irrigation policy supporting the adoption of on-farm water storages (OFS)	Consideration of small water storages with a total capacity for the whole basin of 8257 GL	No lead times or delay associated to emergent global events

Ecological flows	Increase of environmental flows by 30% compared to present values	Delayed by 10 years when considering more than two low flow events in a decade

3.3. Summary of the scenarios (future and water resources development and management) and actions used to achieve acceptable rural income objective and design adaptation pathways.

Exogenous scenarios		
Label	**Definition**	**Description**
hist	Historical data	"Current" climate and socioeconomic situation in the basin. Climate datasets are based on historical datasets from 1961 to 2005.
cc1	Climate change, dry conditions – increased global socioeconomic inequalities	Drier climate in the basin associated with a small increase in temperatures (RCP 2.6) accompanied by increased socioeconomic inequalities worldwide leading to increased disparities in terms of economic opportunities and political power and societal stratification across and within countries (SSP4). Socio-economic and climate changes are influencing population migration for job opportunities in urban centers and, in the context of the BRB, are responsible for a decadal rural exodus of 2.1% to urban centers in the basin.
cc2	Climate change, wet conditions – increased global socioeconomic inequalities	Wetter climate in the basin associated with a larger increase in temperatures (RCP 8.5) similarly accompanied by increased socioeconomic inequalities worldwide (SSP4). Migration is modelled as leading to a decadal rural exodus of 4.7% to urban centers in the basin.
Economic actions with or without implementation of proposed dams by 2020		
Label	**Definition**	**Description**

bau1	No change in the current situation – completion of ongoing dam projects in 2020	Business as usual scenario considering a continuous annual irrigation growth rate of 6.6% and culturable command area (CCA)	
bau2	Implementation of proposed dams and completion of all dam projects in 2020	Business as usual scenario considering a continuous annual irrigation growth rate of 6.6% and culturable land availability (CCA) provided by the additional implementation of proposed major and medium dams with existing and on-going projects.	
irr1	Irrigation development – ongoing dams completed in 2020	Irrigation development scenario considering a continuous annual irrigation growth rate of 8.32% and culturable land availability (CCA) provided by existing and ongoing major and medium dams; the latter completed by 2020.	
irr2	Irrigation development – ongoing and proposed dams completed in 2020	Irrigation development scenario considering a continuous annual irrigation growth rate of 8.32% and culturable land availability (CCA) provided by the additional implementation of proposed major and medium dams with existing and on-going projects.	
Additional supply and management actions			
Label	**Definition**	**Management action**	**Description**
wwt20	Treatment of 20% of D&I effluents	Supply	D&I effluent management policy increases by 20% the amount of treated D&I effluent returned to surface water
wwt50	Treatment of 50% of D&I effluents	Supply	D&I effluent management policy increases by 50% the amount of treated D&I effluent returned to surface water

ofs	On-farm water storages	Demand	Implementation of on-farm (water) storage to reduce irrigation use from surface water
eff	Irrigation application efficiency	Demand	Change in irrigation efficiency supported by policies aiming at improving water productivity by reducing irrigation water losses
eflow	Environmental flows	Demand	Ecological flows increase for fisheries production

4. Additional results

4.1. Information requirements common to DAPP and the frameworks at its origin

Systems approach: Use of computational scenarios or expert inputs to evaluate actions

DAPP: Focus on exploratory modelling to evaluate options across assumptions

Systems approach: Evaluation of performance in terms of case-specific objectives

Assessment of vulnerabilities and opportunities, Evaluation of actions

Specific identification of vulnerabilities of base case

Identification of tipping points for the system and for specific actions, and expected timing under identified major vulnerable scenarios

Definition of robustness metrics to evaluate effectiveness of actions

Systems approach: Selection of plausible actions to support achievement of specific system objectives, with trade-offs between actions

Assessment of vulnerabilities and opportunities

Evaluation of limits of current policy

Evaluation of actions

Identification of near-term and alternative (medium-term and long-term) actions

Evaluation of identified actions' lead time to consider the expected timing for decision points and actions' feasibility

Design and evaluation of adaptation pathways

Evaluation of adaptation pathways combining actions, represented as a "metro-map" with a scorecard

The map displays the different routes to a specific objective, timeline or conditions for vulnerable scenarios, adaptation tipping points for the different actions, decision points (signposts) and triggers to change of actions.

Systems approach: Selection of alternatives

Designing the adaptive plan

Near-term actions are specified. These actions should be "no-regret" to allow for future actions to be easily implemented

Anticipatory actions are specified with their associated conditions and timing

Signposts and triggers to monitor the plan post-implementation need to be clearly defined with their associated contingency actions

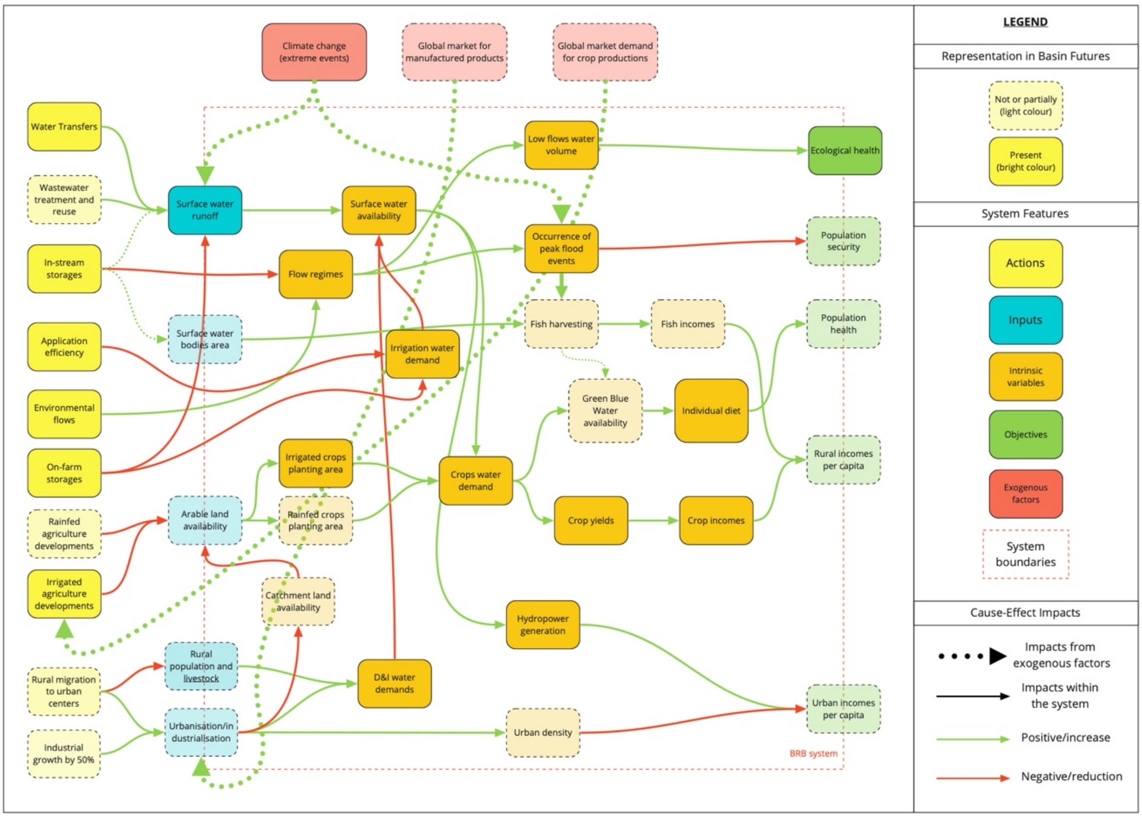
The robustness of the plan is evaluated against future scenarios and emergent events

Systems approach: Implementation of the plan

Implementation of near-term actions and the monitoring plan

4.2. Full conceptual representation for the Brahmani River Basin system

The figure presents the comparison of two perspectives: a user and the model' ones. In light colors, framed with dash lines, are misaligned information resulting from a partial or absence of representation of a feature of interest in the tool.



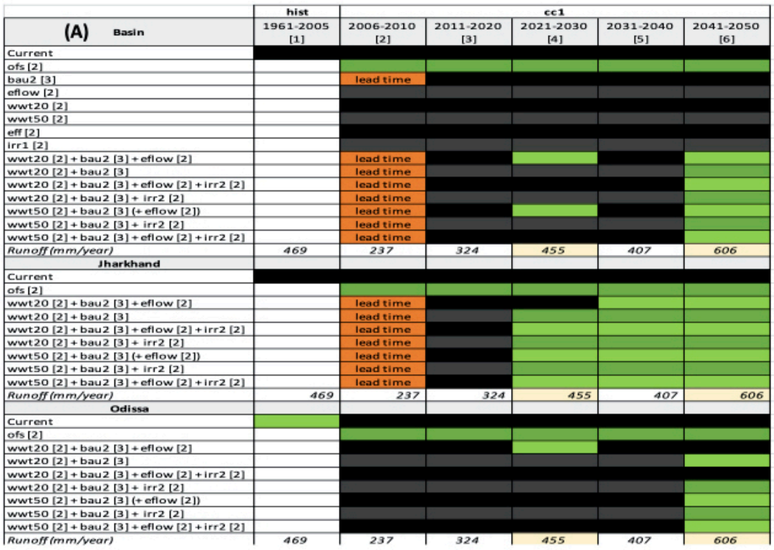
4.3. Examples of solutions to represent minimum information requirements in the Basin Futures tool to evaluate the robustness of actions against future scenarios in the context of the BRB case study.

Factor to model		
Step in DAPP	**Type of solution strategy**	**Representation in BRB case**
Global and regional socio-economic changes		
Conceptual representation (step 1) and ATP identification (steps 2 and 3)	Assumption-based	Assumption of global socioeconomic changes underpinning increased global inequalities based on population estimates (KC & Lutz, 2017) and associated urban ratio (Jiang & O'Neill, 2017) for India using the SSP4 scenarios database (Calvin et al., 2017; Riahi et al., 2017)
Livestock water demand		
Conceptual representation (step 1); evaluation of tipping points for the system (step 2) and for actions (step 3); estimation of the performance of adaptive pathways (step 4); indicator to monitor the plan (step 7)	Calculation-based	Calculation of livestock water demand based on estimates of the current livestock population, growth rate, average daily water consumption per capita (ICID, 2005). The values are then used to re-calculate existing indicators (e.g., blue water scarcity) or estimate new ones (e.g., supply reliability for irrigation).
Population health		
Conceptual representation (step 1); evaluation of tipping points for the system (step 2) and for actions (step 3); evaluation of adaptation pathways (step 4).	Calculation-based	Estimation of the Green Blue Water Scarcity indicator (Kummu et al., 2014) as a proxy for population health objective (new indicator).
Climate change datasets		

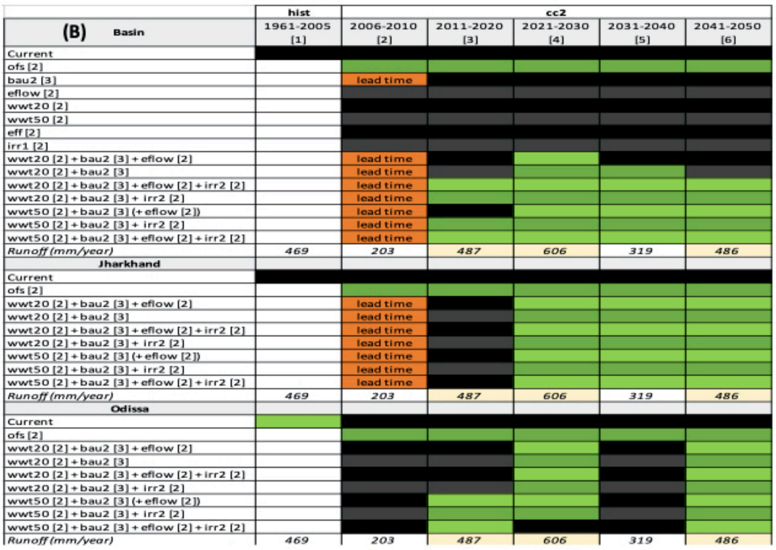
Conceptual representation (step 1) and ATP identification (steps 2 and 3)	Implementation-based	The initial version of Basin Futures did not include climate change databases. Discussions of the feasibility to implement climate change datasets within the tool has contributed to the addition of this extra-feature to the tool.
Access to monthly timeseries		
To evaluate tipping points for the system (step 2) and for actions (step 3) and evaluate adaptation pathways (step 4).	Implementation-based	To be able to (re)calculate (new) parameters/indicators, the developers were able to make available monthly timeseries for the different estimated variables in the tool
Rainfed crop yields		
Conceptual representation (step 1) and evaluation of adaptation pathways (step 4).	Calculation-based	Estimation of rainfed crop yields based on the use of climate timeseries from the tool and estimation of crop water requirements (Doorenbos & Pruitt, 1977)
Domestic and industrial (D&I) effluent water management		
Conceptual representation (step 1), evaluation of tipping points for the action (step 3), and estimation of the performance of adaptation pathways (step 4).	Assumption-based	Assumption that the proportion of D&I water return could be used as a proxy for D&I effluent treatment and water quality. Only the treated portion of non-consumed water is set as water return from D&I in the modelling tool. For example, for no water treatment, water return is set to 0%.

4.4. ATP identification for actions aiming at achieving the rural incomes objective

The table provides the full results obtained based on the consideration of timeseries to identify the expected timing for ATPs for actions considered alone or in combination. The identification of ATPs based on the consideration of the supply reliability (frequency of years where the supply could answer the demands with an efficiency of 85%). Conditions of failure (black) are identified for more than one failure over 5 years for each transient scenario (numbers under brackets are associated with different period or time range and transient scenarios). The acronyms are defined in the table in section 3.3. When considering the completion of either ongoing or proposed dams, a lead time of 20 years was assumed. For simplification purposes, we assumed the implementation of this measures only in period 3. The results are presented both at the basin and administrative (the two states) scales. As we observed non-linear results, the mean annual runoff for each transient scenario was added to the table to consider the influence of non-linear climate change datasets on the identification of ATPs. Highlighted in yellow are runoff values for which some combinations of actions do not fail under their future scenarios.



	hist	cc1				
(A) Basin	1961-2005 [1]	2006-2010 [2]	2011-2020 [3]	2021-2030 [4]	2031-2040 [5]	2041-2050 [6]
Current						
ofs [2]						
bau2 [3]		lead time				
eflow [2]						
wwt20 [2]						
wwt50 [2]						
eff [2]						
irr1 [2]						
wwt20 [2] + bau2 [3] + eflow [2]		lead time				
wwt20 [2] + bau2 [3]		lead time				
wwt20 [2] + bau2 [3] + eflow [2] + irr2 [2]		lead time				
wwt20 [2] + bau2 [3] + irr2 [2]		lead time				
wwt50 [2] + bau2 [3] (+ eflow [2])		lead time				
wwt50 [2] + bau2 [3] + irr2 [2]		lead time				
wwt50 [2] + bau2 [3] + eflow [2] + irr2 [2]		lead time				
Runoff (mm/year)	*469*	*237*	*324*	*455*	*407*	*606*
Jharkhand						
Current						
ofs [2]						
wwt20 [2] + bau2 [3] + eflow [2]		lead time				
wwt20 [2] + bau2 [3]		lead time				
wwt20 [2] + bau2 [3] + eflow [2] + irr2 [2]		lead time				
wwt20 [2] + bau2 [3] + irr2 [2]		lead time				
wwt50 [2] + bau2 [3] (+ eflow [2])		lead time				
wwt50 [2] + bau2 [3] + irr2 [2]		lead time				
wwt50 [2] + bau2 [3] + eflow [2] + irr2 [2]		lead time				
Runoff (mm/year)	*469*	*237*	*324*	*455*	*407*	*606*
Odissa						
Current						
ofs [2]						
wwt20 [2] + bau2 [3] + eflow [2]						
wwt20 [2] + bau2 [3]						
wwt20 [2] + bau2 [3] + eflow [2] + irr2 [2]						
wwt20 [2] + bau2 [3] + irr2 [2]						
wwt50 [2] + bau2 [3] (+ eflow [2])						
wwt50 [2] + bau2 [3] + irr2 [2]						
wwt50 [2] + bau2 [3] + eflow [2] + irr2 [2]						
Runoff (mm/year)	*469*	*237*	*324*	*455*	*407*	*606*



	hist	cc2				
(B) Basin	1961-2005 [1]	2006-2010 [2]	2011-2020 [3]	2021-2030 [4]	2031-2040 [5]	2041-2050 [6]
Current						
ofs [2]						
bau2 [3]		lead time				
eflow [2]						
wwt20 [2]						
wwt50 [2]						
eff [2]						
irr1 [2]						
wwt20 [2] + bau2 [3] + eflow [2]		lead time				
wwt20 [2] + bau2 [3]		lead time				
wwt20 [2] + bau2 [3] + eflow [2] + irr2 [2]		lead time				
wwt20 [2] + bau2 [3] + irr2 [2]		lead time				
wwt50 [2] + bau2 [3] (+ eflow [2])		lead time				
wwt50 [2] + bau2 [3] + irr2 [2]		lead time				
wwt50 [2] + bau2 [3] + eflow [2] + irr2 [2]		lead time				
Runoff (mm/year)	*469*	*203*	*487*	*606*	*319*	*486*
Jharkhand						
Current						
ofs [2]						
wwt20 [2] + bau2 [3] + eflow [2]		lead time				
wwt20 [2] + bau2 [3]		lead time				
wwt20 [2] + bau2 [3] + eflow [2] + irr2 [2]		lead time				
wwt20 [2] + bau2 [3] + irr2 [2]		lead time				
wwt50 [2] + bau2 [3] (+ eflow [2])		lead time				
wwt50 [2] + bau2 [3] + irr2 [2]		lead time				
wwt50 [2] + bau2 [3] + eflow [2] + irr2 [2]		lead time				
Runoff (mm/year)	*469*	*203*	*487*	*606*	*319*	*486*
Odissa						
Current						
ofs [2]						
wwt20 [2] + bau2 [3] + eflow [2]						
wwt20 [2] + bau2 [3]						
wwt20 [2] + bau2 [3] + eflow [2] + irr2 [2]						
wwt20 [2] + bau2 [3] + irr2 [2]						
wwt50 [2] + bau2 [3] (+ eflow [2])						
wwt50 [2] + bau2 [3] + irr2 [2]						
wwt50 [2] + bau2 [3] + eflow [2] + irr2 [2]						
Runoff (mm/year)	*469*	*203*	*487*	*606*	*319*	*486*

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Engaging Users In Critical Appraisal Of Computer Model Software: Introducing the Critical Appraisal Approach (CAA)

B. Supplementary Material – Chapter 4

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A. Questions used for the Expert Review and semi-structured interviews.

1. **Effectiveness to the user**

We are interested in your general experience as a user interacting with the BF tool.

Q1: In light of the BF intended uses and areas of the applications, do you think that the tool clearly addresses its target scope and intended user audience?

Q2: Do you think that the tool function properly, provide you with a good experience and deliver on its aims?

Q3: Reflecting on your user experience, can you think of anything that would improve the user interface experience?

- If you have any suggestions, would you categorise them as ‘must have’ or ‘nice to have’ and why?

2. **Data coverage**

We are interested in your expert assessment of the data coverage to allow a user to answer the three questions at the outset of the document.

Q4: Turning now to data coverage, do you think the BF tool has a good coverage of global data?

- If not, what are, in your opinion, the major gaps?

Q5: Reflecting now on the appropriateness of data temporal and spatial scale, do you think you have all the information you need to make a judgment?

- If not, what other data do you think you need?

Q6: Still regarding the spatial and temporal scales of data, do you think the available data are at the appropriate spatial-temporal scales to help you answer the three questions?

Q7: Turning now to the adequacy of the climate change scaling approach to the application, do you think it is appropriately represent in the BF tool?

- If not, what are the major gaps?
- Could you think of anything that would improve climate change function in the UI?

Q8: Overall, reflecting on data coverage in BF, can you think of anything that would improve it?

- If you have any suggestions, would you categorise them as ‘must have’ or ‘nice to have’ and why?

3. **Choice of models**

We are interested in your expert assessment of the models underpinning the BF tool.

Q9: Bearing in mind that the BF is designed as a high-level water resource assessment tool, do you think it represents the most important processes (i.e. biophysical and management) essential for this purpose?

- For example, there is no current representation of concepts such as resource allocation, accounting, trade, etc.

Q10: Regarding the choice of models built in the BF tool, do you think the models’ (scope, boundary, variables and relationships) fit the intended uses? Please provide examples to illustrate your answer.

Q11: Would you say that the models match the required spatial and temporal granularity required for the BF areas of application?

- If yes, then why? Otherwise, why not?

Q12: Do you think the models are suitable for use with the applied data within BF? For that question, could you broadly assess the performance of the models and quality of the analysis provided by BF with covering the extent to which they are currently been used.

Q13: Do you think any of the models could be replaced with other (potentially modelled externally) data sources? E.g. replace runoff model with direct use of global runoff data.

Q14: Turning to the indicators used, do you think they are useful?

- If yes, then why? Otherwise, why not?

Q15: Overall, reflecting on the models and indicators used in BF, can you think of anything that would improve the choice of models and indicators?

- If you have any suggestions, would you categorise them as ‘must have’ or ‘nice to have’ and why?

4. **Uncertainty communication**

We are interested in your expert assessment of how uncertainty is communicated in the BF.

Q16: Do you think the level of uncertainty is adequately communicated?

Q17: What inclusions would increase transparency in the tool?

- Reflecting on your suggestions, would you categorise them as 'must have' or 'nice to have' and why?

5. Groundwater

Q18: Looking at GW representation, despite its current unavailability, do you think it is a critical factor for the BF to include?

- If yes, then why? Otherwise, why not?

Q19: Would you like to share any thoughts of how groundwater may be brought into the BF?

- Based on your suggestions, would categorise them as 'must have' or 'nice to have' and why?

6. Documentation

Q20: Regarding the documentation provided, do you think it was adequate and allow you to answer questions that arise while using Basin Futures?

Q21: Reflecting on the documentation, can you think of anything that would improve your understanding and usability of the UI?

- If you have any suggestions, would you categorise them as 'must have' or 'nice to have' and why?

Wrapping up

Given your overall reflection about the BF tool, any other suggestions for the BF improvement?

- What do you think the most important 'must have' improvement?

B. Illustration of the interactive report developed based the heuristic approach findings.
A wireframe approach was used to report findings to developers following the evaluation of uncertainty communication in BF. Appendix C outlines the prioritisation of issues and proposed solutions. The interactive report was designed to assist developers in navigating these issues and solutions, considering suggested levels of priority and the perceived efforts required for implementing solutions.

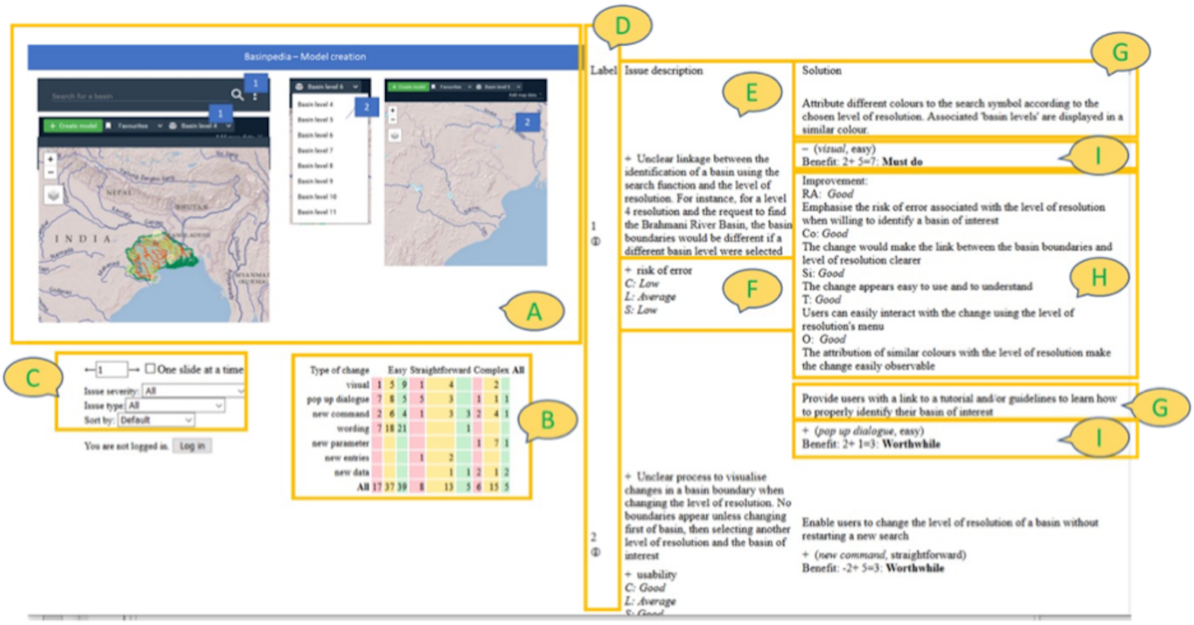

Figure B. Illustration of the interactive report and recommendations for developers.
A – Location of identified issue within the BF interface.

B – Summary matrix incorporating the type of solutions, the level of effort required by developers to implement a solution, and the priority level for each issue. The numbers indicate the total count of solutions with similar types and levels of effort for developers. Clicking on these numbers reveals detailed information about the corresponding solutions and their respective issues.

C – Filters for refining the visualisation of issues and solutions. Options include selecting slides (i.e., screenshot of BF' user interface with labelled issues), issue severity, issue type, or priority of implementation levels (under 'sort by').

D – Issue label number, with an option to show all solutions related to this issue.

E – Detailed description of the issue.

F – Type of issue and its associated score.

G – Solution description.

H – Reason for the subjective impact of a solution along with an associated qualitative score.

I – Priority level for an issue, with additional details under brackets specifying the type of solution and the level of effort required for developers.

C. Description of the approach for prioritising issues and solutions.

To maintain consistency and ensure rigour in evaluating and prioritising issues, a ranking approach was developed, that draws on two frameworks and a qualitative assessment of the effort for implementing suggested solutions. The CRELE framework (e.g., Dunn & Laing, 2017[4]) was used to evaluate the impact of issues on the credibility, salience and relevance of information conveyed by a modelling tool. The Diffusion of Innovation framework (Rogers et al., 2014[5]) was employed to consider the potential benefits of solutions in addressing issues and their adoption. Self-reflective questions were utilised to reflect on the impact of issues and solutions on criteria associated with these two frameworks, as presented in Table C.

Table C. Criteria of evaluation to prioritise issues and solutions.

<table>
<tr><th colspan="3">CRELE Framework</th></tr>
<tr><th>Criteria</th><th>Reflective questions</th><th>Qualitative appraisal of the level of (perceived) uncertainty</th></tr>
<tr><td>Credibility</td><td>Do I feel confident in the information provided?
What could limit trust?</td><td rowspan="3">Is the issue with high, moderate or low consequences for the criterion relative to the current state?</td></tr>
<tr><td>Salience/relevance</td><td>Is the information conveyed representative of the scale, context, and components of a problem or system I want to analyse?
What information needs to be represented?</td></tr>
<tr><td>Legitimacy</td><td>Is the information provided clear and understandable?
Can I access supportive information if needed?
Can I solve a problem of interest based on the information provided?
What information need to be accessible/included?</td></tr>
</table>

[4] Dunn, G., & Laing, M. (2017). Policy-makers perspectives on credibility, relevance and legitimacy (CRELE). Environmental Science & Policy, 76, 146–152. https://doi.org/10.1016/j.envsci.2017.07.005

[5] Rogers, E. M., Singhal, A., & Quinlan, M. M. (2014). Diffusion of Innovations. In An integrated approach to communication theory and research (2nd Edition, Vol. 5, pp. 432–448). Routledge. http://www.lamolina.edu.pe/postgrado/pmdas/cursos/innovacion/lecturas/Obligatoria/17%20-%20Rogers%201995%20cap%206.pdf

<table>
<tr><th colspan="3">Diffusion of Innovation Framework</th></tr>
<tr><td>Relative advantage</td><td>How would the solution benefit the tool?</td><td rowspan="5">Is the solution enhancing, impairing, or have neutral effects on the criterion relative to the current situation?</td></tr>
<tr><td>Compatibility</td><td>Would the solution reduce the current effort while realising a task?</td></tr>
<tr><td>Simplicity</td><td>Is the solution easy to understand/use?</td></tr>
<tr><td>Trialability</td><td>Is the solution enhancing experimentation with the tool?</td></tr>
<tr><td>Observability</td><td>Is the solution easily visible?
How long would it take to observe benefits from the solution?</td></tr>
</table>

The scoring process involves a mixed qualitative-quantitative approach, described as followed:

- For criteria related to CRELE (Table C) assessing the perceived impacts of an issue on information quality:

  +1 is assigned to high consequences,

  0 to moderate consequences,

  -1 for low consequences.

- For criteria related to the Innovation Adoption framework, scoring reflects the perceived impact of solutions:

  +1 is allocated for solutions with enhancing effects,

  0 for solutions maintaining the current situation,

  -1 for solutions impairing the current situation.

These numerical values are then summed to provide a final score for prioritising an issue and its suggested solution. Priority levels are defined as follows:

- High priority level (“must have”): scores of 6 and above.
- Moderate priority level (“worthwhile”): scores ranging from 3 to 5.
- Low priority level (“possible in the future”): scores below 3.

To this quantitative ranking, a qualitative level of effort required for solution implementation by developers is assigned, categorised as low, medium, high. This determination is based on user perception regarding the ease of implementing a solution and whether consultation with the development team is necessary.

D. Identified issues and solutions in Basin Futures

The following tables provide raw findings from the two evaluations of Basin Futures. For Table D.1, the definitions for the types of issues and solutions are provided in Appendix A.

Table D.1. Identified issues and solutions from the Basin Futures' evaluation of uncertainty communication using a heuristic approach.

Issue label	Issue location	Issue description	Issue type	Why I choose this issue?	Solution label	Solution description	Solution type
1	Basinpedia - Model creation	Unclear linkage between the identification of a basin using the search function and the level of resolution. For instance, for a level 4 resolution and the request to find the Brahmani River Basin, the basin boundaries would be different from the same request done with selectioning another level of resolution	Risk of error	A user could not be aware that the chosen level of resolution may prevent the identification of the expected basin boundaries due to the selection of a level of resolution	1	Attribute different colours to the research symbol according to the chosen level of resolution. Associated 'basin levels' are displayed in a similar colour.	Visual
					2	Provide users with a link to a tutorial and/or guidelines to learn how to properly identify their basin of interest	Pop up window
2	Basinpedia - Model creation	Unclear process to visualise changes in a basin boundary when changing the level of resolution. No boundaries appear unless changing first of basin, then selecting another level of resolution and the basin of interest	Usability	A user may not realise immediately how to face that issue or would have to manually tried to identify a basin of interest	1	Enable users to change the level of resolution of a basin without restarting new research	New command
					2	Provide users with a link to a tutorial and/or guidelines to learn how	Pop up window

						to properly identify their basin of interest	
3	Basinpedia - Model creation	Wrong identification of districts/localities' names	Risk of error	A user may trust the model information and identify wrongly a reach name	1	Remove information regarding the reach name to prevent confusions	Wording
4	Basinpedia - Model creation	Missing information regarding the source	Uncertainty	Population information could be outdated	1	Add information regarding the source, time covered, reference and URL link (if existing)	Pop up window
5	Basinpedia - Model creation	Missing information regarding the source	Missing information	To clarify how reaches are delineated and the estimation of areas	1	Add information regarding the source, time covered, reference and URL link (if existing)	Pop up window
6	Basinpedia - Model creation	Unclear identification of storages when close to administrative areas boundaries	Uncertainty	To clarify the size and importance of storages found in a reach and within administrative areas	1	Select distinct colours for administrative areas boundaries and storages	Visual
7	Basinpedia - Model creation	Missing information regarding the sources for the different parameters	Uncertainty	Information could be outdated	1	For each parameter displayed on the map, provide information regarding the source, time covered, reference and URL link (if existing)	Pop up window

8	Basinpedia - Model creation	Redundant information	Redundancy	The line below the title should provide an addition	1	Provide the URL directly	Wording
9	Basinpedia - Model creation	Unclear whether the estimates for land uses represent current values	Uncertainty	Users may not notice and/or be aware that estimates are not based on historical values	1	Put the maximum time extent value in a prominent colour	Visual
				Users may not notice and/or be aware that estimates are not based on historical values	2	Bring 'show metadata' command (currently at the bottom of the page) next to "Graph" and "Table" and display in a prominent colour	Visual
10	Basinpedia - Model creation	Inability to download land uses' data	Missing information	Users may need to refer to land uses values for scenario edition and exploration to design more realistic scenarios considering other land uses	1	Add a command enabling users to download data for each pre-defined reach under Basinpedia	New command
					2	Under scenario editor, add a box with current (year) land uses	Pop up dialogue
11	Basinpedia - Model creation	Unclear how land uses' estimates will vary according to development scenarios and climate changes	Uncertainty	Land uses changes could only be done on irrigation land. Other potential changes associated with other socio-economic, infrastructural, and	1	Develop more land uses' options under the scenario editor such as pastoralism/grazing, ecological restoration, forestry development, urbanisation	New parameters

				ecological developments are ignored.			
12	Basinpedia - Model creation	Unclear whether protected areas are displayed for the whole basin (delineated in light and dark green) or for each reach	Missing information	Some of the displayed parameters, such as land uses, are displayed only for a selected reach (in dark green), whereas other parameters summarise information for the whole basin (or selected area in light and dark green), which could make users unaware of the scale used for the results	1	Add a note to precise the dimension encompassed by the values displayed in the table. For example, add an (*) after "Protected areas" and precise in a sentence "* for the whole area delineate in dark and light green"	Wording
					2	Add a symbol next to "protected area" which open a dialogue box where precision regarding the scale encompassed by "protected areas" is clarified. For instance, "Protected areas are given for the whole basin (i.e., the area delineated in light and dark green)"	Pop up window

13	Basinpedia - Model creation	Unclear whether IUCN values are representative of protected areas' status	Uncertainty	No references are mentioned. IUCN values could have been selected based on old datasets.	1	Add references for the IUCN dataset at the bottom of the table(s)	Wording
					2	Together with the complete references, add the time extent under brackets	Wording
14	Basinpedia - Model creation	Unclear whether the size of the protected areas is representative of the whole protected area or the size within a basin	Missing information	No precision regarding the nature of the size displayed and the proportion of the protected area within a basin	1	If representative of the whole protected area, precise that values correspond to the "Total size"	Wording
					2	Add a supplementary column in the table displaying the "% within the basin"	New entry
15	Basinpedia - Model creation	Unclear whether the zoom function enable users to visualise the location of the selected protected area	Risk of error	When numerous protected areas are closed to each other and in the same colour, it is unclear whether the zoom function enable users to visualise the location of the selected protected area	1	Present the selected protected area in a prominent colour, different from other protected areas	Visual
16	Basinpedia - Model creation	Unclear wording suggesting that basins are in all cases "transboundary river basins"	Risk of error	In the case of non-transboundary river basin, "overlaps" suggest that the	1	Replace "overlaps" by "encompasses" to clarify meaning	Wording

				basin belongs to more than one country			
17	Basinpedia - Model creation	Unclear proportion of a basin laying within a country	Missing information	In the case of transboundary basins, the proportion of a basin within a country is missing. This information could be of importance for evaluating the feasibility and risks associated with different scenarios	1	Present the name of a country and its proportion in a basin in a table	Visual
					2	Display the boundaries of the different countries in a prominent colour	Visual
18	Basinpedia - Model creation	Unclear whether indicators reflect the whole basin information or of a selected reach	Uncertainty	If reflective of the whole basin stress or level of awareness, users could have a limited visibility of variations between reaches	1	Add a note to precise the dimension encompassed by the indicator. For example, add an (*) after "Stress indicators" and precise in a sentence below the title "* for the whole area delineate in dark and light green"	Wording
					2	Present the different indicators' results, using a similar presentation as for current results, in a table for all reaches (light and dark green)	Visual

						and a select reach (dark green)	
19	Basinpedia - Model creation	Unclear whether the blue water scarcity indicator represents the current situation	Uncertainty	The absence of complete references reduces users' ability to evaluate the fitness of estimates with the current situation	1	Precise the complete reference(s) and, when referring to a website, provide the URL link	Wording
20	Basinpedia - Model creation	Unclear understanding of what is encompassed by "variations"	Missing information	Reduce users' ability to properly identify how the indicator is estimated and understand what the value implies	1	Keep the definition from the source and replace "variation" by "average between year variability of available water supply (both SW and GW). Higher values are indicative of wider variations in available supply."(WRI Aqueduct) to clarify the nature of the value displayed	Wording
21	Basinpedia - Model creation	Unclear whether the indicator estimates are representative of the current situation in a basin	Uncertainty	Reduce users' ability to evaluate the fitness of estimates with the current situation	1	Precise the time extent in the definition to clarify over which period estimates were calculated	Wording

					2	Provide the URL for the dataset where the definition and time extent for the indicator are specified	New command
22	Basinpedia - Model creation	Unclear understanding of what is encompassed by "variations"	Missing information	Reduce users' ability to properly identify how the indicator is estimated and understand what the value implies	1	Keep the definition from the source and replace "variation" by "average within year variability of available water supply (both SW and GW). Higher values are indicative of wider variations in available supply."(WRI Aqueduct) to clarify the nature of the value displayed	Wording
23	Basinpedia - Model creation	Unclear whether the indicator estimates are representative of the current situation in a basin	Uncertainty	Reduce users' ability to evaluate the fitness of estimates with the current situation	1	Precise the time extent in the definition to clarify over which period estimates were calculated	Wording
					2	Provide the URL for the dataset where the definition and time extent for the indicator are specified	Wording

24	Basinpedia - Model creation	Unclear whether the current indicator is representative of current flood events risk	Uncertainty	Users may miss the time extent values	1	Emphasise the maximum time extent in a prominent colour to raise users' awareness about the time extent covered	Visual
25	Basinpedia - Model creation	Unclear what type of flood events is used for the indicator	Uncertainty	Different flood events frequency (percentage exceedance) could be used for the estimate	1	Clarify the frequency of return or percentage exceedance used to calculate the value for this indicator or the type of flood event. For example, for the latter, instead of "the number of floods recorded" re-write as "the number of LARGE/VERY LARGE/EXTREME floods recorded (less than 1 every 20 years/between 1 every 20 years to 1 every 100 years/over 1 over 100 years, respectively)	Wording
					2	Provide the URL for the dataset where the definition of the indicator and nature of	New command

						the flood event is documented	
26	Basinpedia - Model creation	Unclear whether the indicator is reflective of the current situation	Uncertainty	The severity of drought events could have evolved to reach different status of stress levels	1	Emphasise the maximum time extent in a prominent colour to raise users awareness about the time extent covered	Visual
27	Basinpedia - Model creation	Unclear source for the indicator	Missing information	Users could not identify with certainty the source at the origin of the indicator	1	Provide the complete reference	Wording
28	Basinpedia - Model creation	Unclear whether the indicator values are calculated based on the source's model of estimation or extracted from the source's model	Uncertainty	The indicator definition does not suggest if values are estimated from the source dataset or calculated	1	If calculated, change "Drought is defined as (…)" by "Drought severity is calculated as (…)". Otherwise, add a sentence in which precision is provided regarding drought means of determination such as "Drought severity values were extracted from the source dataset"	Wording
29	*Basinpedia - Model creation*	*Unclear source for groundwater stress indicator*	*Missing information*	*Users could not identify with certainty the source at the origin of the indicator*	*1*	*Provide the complete reference*	*Wording*

		(GW function is under development)					
30	*Basinpedia - Model creation*	*Unclear whether the indicator values are calculated based on the source's model of estimation or extracted from the source's model (GW function is under development)*	*Uncertainty*	*The indicator definition does not suggest if values are estimated from the source dataset or calculated*	*1*	*If calculated, precise "Groundwater stress is calculated as (...)". Otherwise, add a sentence providing indication about the source and means of estimation of the indicator*	*Wording*
31	Basinpedia - Model creation	Unclear whether the quality of the source for the indicator reflect its scientific validity and strength	Uncertainty	The source for the indicator is not supported by peer-reviews	1	Provide peer-review sources supporting the effectiveness of the approach to certify the level of public awareness	Wording
					2	Emphasise the source for the indicator in a prominent colour to raise users' awareness about the origin for estimating the indicator values	Visual
32	Basinpedia - Model creation	Unclear whether different sources and time coverages are considered	Uncertainty	The definition does not clarify that different media sources and time extents	1	In a table, provide users with the type of issues, number of different sources of media, type	Pop up window

				are considered for a water-related issue		of media, and time extent	
33	Basinpedia - Model creation	Unclear how the impact of different scenario and options may impact these indicators	Uncertainty	There is no further use of the indicators in the model. However, they could be computed and useful to evaluate the impact of different scenarios and effectiveness of different options	1	Under "Scenario results", add the values for the different indicators (except for media coverage) as for the blue water scarcity indicator to provide users with additional information regarding different risks	New parameters
34	Basinpedia - Model creation	Unclear whether the status for fish species is currently the same	Uncertainty	Information for fishes' status and changes in fish populations (e.g., increase of invasive species, reduction in native species) is outdated	1	Emphasise in a prominent colour "Year" in the table to raise awareness about the time when fish species were last assessed	Visual

35	Basinpedia - Model creation	Unclear how scenarios and infrastructural options would affect fish populations	Uncertainty	Information about fish species and status is only provided as an ecological indicator for aquatic system health when selecting a basin. Ecological impacts are then only relying on the blue water scarcity index, without use of alternative indicators for aquatic systems' health. There is no sound evaluation of ecological status and impact limiting BF's consideration of ecological impacts in the trade-offs between social, economic, and ecological goals	1	Enable users to select one or more indicator species for a dedicated basin from the list provided under Basinpedia. Fishes could be allocated a type of indicator such as spawning, aquatic system health. The parameter could be added under "environment" or "agriculture". For the former, changes in flow regimes and their impacts on the indicator could be represented under "scenario results" as a heat map displaying changes in flow percentiles and associated fish species impact (%). For "agriculture", the market price of fishes, nutrition, proteins, and density could be set and changes in flow requirements would impact these	New parameter

						parameters' values, displayed under scenario results as "fisheries" for instance	
36	Scenario editor - Table summary	Unclear how users could change the reaches labels with existing names	Usability	Users may notice the editor logo in the table, but it is unclear how they could personalise the different reaches	1	Emphasise the edition logo and the name of the reaches (e.g. Reach 3) in a prominent colour to raise user awareness about the possibility to personalise the reaches' names	Visual

					2	When clicking on the logo, information regarding how to change the name of the reaches could be provided	Pop up dialogue
					3	Provide users with a link to a tutorial and/or guidelines to learn how to personalise reaches	Pop up dialogue
37	Scenario editor - Table summary	Unclear correspondence between the logos and "climate"	Risk of error	This part of the table provides information about the status of the calibration process for the rainfalls (cloud), evapotranspiration (plant) and runoff (balance). However, the choice of the logos could be confusing for the evapotranspiration one and the agriculture one.	1	Change the logo for evapotranspiration for PET to limit the confusion with the agriculture one	Wording
38	Scenario editor - Table summary	Unclear aim for the tick boxes under climate	Risk of error	This part of the table enables users to check if the calibration process for climate and runoff parameters have been completed before running scenario simulations. The current displays is not explicit enough.	1	Add a logo displaying process gears next to climate	Visual
					2	Replace "climate" by "climate calibration process" to raise users' awareness about the	Wording

						status for climate and runoff calibration	
39	Scenario editor - Table summary	Unclear designation for the "climate" column in the table	Missing information	Runoff is associated with hydrological data and not climate data	1	Change "climate" for "climate and runoff"	Wording
40	Scenario editor - Table summary	Unclear whether "crops" represent rainfed and irrigated crops or irrigated crops only	Missing information	Need to clarify if the values belong to " all crops" or "irrigated crops" only for users to avoid confounding area estimates for cropland (rainfed and irrigated) under land uses.	1	Add "irrigated crops" to clarify meanings	Wording
41	Scenario editor - Runoff calibration	Unclear what is encompassed by calibration	Missing information	The label do not provide users with a straightforward of the parameter to calibrate	1	Replace calibration by either "runoff" alone or "runoff calibration"	Wording
42	Scenario editor - Runoff calibration	No information regarding the model used to compute the four parameters allowing for runoff calculations	Missing information	The current interface is not providing information and details about the model used for calculating the model parameters' values	1	Restore the link with information regarding the GR4J model for users to consider details regarding the model means of estimation of runoff	Pop up window

43	Scenario editor - Runoff calibration	Unclear whether the values computed are within the range considered by the model for calibrating runoff based on mean annual or monthly runoff target	Uncertainty	Information regarding the fitness of calculated values within the range of values considered by the model are not noticeable	1	Display values under or above the range of considered values by the model in a prominent colour	Visual
					2	Under "description" in the table, add the definition of the parameter and the range of values considered appropriately by the model	New data
44	Scenario editor - Runoff calibration	Unclear whether results from the model calculated on the basis of parameters value outside the range of values considered by the model would provide accurate runoff estimates	Uncertainty	The model has been demonstrated to estimate accurate runoff values for specific range of parameters' values, but there is no information about the performance of the model in situations where one or more parameters' values do not fit in that range or whether the model is using default values in this context	1	Under "description" in the table, add a brief explanation of how the model behaves when using one or more values outside the model's range	New data

45	Scenario editor - Runoff calibration	Unclear whether users will ensure that applied values to reaches would be entirely calibrated before running scenarios	Usability	Ones may assume that applied values to reaches are automatically processed and changed, which may not be the case	1	Under the Summary Table, for runoff, displays the box without a tick but a running gear in a prominent colour for users to be aware that runoff calibration is not completed	Visual
					2	If running a scenario and the calibration process is not completed, make a dialogue window appear with a warning informing user that the calibration process is not completed	Pop up window
46	Scenario editor - Runoff calibration	Unclear formulation for the rainfall-runoff title	Risk of error	Users may be confused by the formulation and may not know if runoff or effective rainfall values are considered	1	Correct the "rainfall/runoff" for "rainfall-runoff" to reduce users' potential confusion	Wording
47	Scenario editor - Runoff calibration	Inability to set chosen values	Uncertainty	Users may want to explore scenarios in which variations in monthly runoff could have different implications for the system and the viability of options,	1	Enable users to change monthly runoff values	New data
					2	Enable users to explore scenarios in future time based on rainfall models	New command

				but are currently limited by one static option			
48	Scenario editor - Storages	Unclear where the reference for Hydrolake dataset, mentioned under 'information' could be found	Missing information	Users could not access the source for the model that identify waterbodies over 10GL	1	Under or next to the definition for considered waterbodies, add the complete references and URL of the model source	Wording
49	Scenario editor - Storages	Unclear identification of the model storages using the research tool	Risk of error	Users could not identify with certainty the identified storage by the model	1	Emphasise the storage of interest using a prominent colour, different from other storages' delineation	Visual
50	Scenario editor - Storages	Unclear sequence of action to visualise storages when using the search tool	Usability	Users may not understand that they have first to activate "show storage" before using the search tool to visualise storages within a reach of interest	1	Add an information box next to "Actions" in which the process to visualise storages is explained	Pop up window
					2	Change the research command to allow for the visualisation of storages even without activating the "show storages" function	New command
					3	Provide users with a link to a tutorial and/guidelines to	New command

						explain how to visualise storages	
51	Scenario editor - Storages	Unclear how to proceed if considering more than one storage	Usability	Users may need to configure a storage aggregating features from multiple major and medium storages of interest in a reach and may have issues in parameterising it	1	Enable users to select more than one storage under "available storages"	New command
					2	Provide users with rules of thumb in how to estimate roughly the surface area of the artificial storage based on the reservoir full capacity	Pop up window
					3	Provide users with a link to a tutorial and/guidelines to explain how to parameterise multiple storages in a reach	New command
52	Scenario editor - Storages	Unclear whether the full supply depth correspond to an average value or a maximum depth	Missing information	Users may not understand how to parameterise the input parameter	1	Provide a definition for the parameter to ease setting	Pop up window
53	Scenario editor - Storages	Unclear whether "total volume" is representative of the "flood level" or "full reservoir level" capacity	Missing information	Users may not understand how to parameterise the input parameter	1	Provide a definition for the parameter to ease setting	Pop up window

54	Scenario editor - Storages	Unclear whether "initial volume" is representative of the "full reservoir level" capacity	Missing information	Users may not understand how to parameterise the input parameter	1	Provide a definition for the parameter to ease setting	Pop up window
55	Scenario editor - Storages	Unclear whether the values for the identified storages are reflective of current ones	Missing information	Users may need to refer to the source to evaluate the model means of evaluating parameters values and time extent	1	Below the table listing the different identified storages, provide complete references for the source for the model and potential URL link	Wording
					2	Provide users with the name of the source, URL link and precise the time extent for the identified storages	Pop up window
56	Scenario editor - Storages	Unclear whether the values for the identified storages are reflective of a situation in time	Uncertainty	Several ongoing projects documented in the literature could now be completed or are still delayed, making the consideration of completing ongoing projects and of implementing proposed projects' impacts on the system and performance in time uncertain	1	Enable users to parameterise storages in time (selection of a month and year), with defining when a storage would be operational	New command
					2	Provide users with a link to a guide or tutorial to consider discrete scenarios when considering storages' implementation and operation times	New command

57	Scenario editor - Agriculture	Unclear whether the total irrigation and drainage system efficiency is considered or just the application efficiency at the field level	Risk of error	Based on the guide, the application efficiency appears to be the parameter of interest. The application efficiency is focused on the technology used at the field level for water conservation. However, there is still a confusion on the nature of the parameter as, if the technology could provide a certain percentage of water provision efficiency, leakages and other losses before the field application level could reduce further the technology efficiency and contribute to more water withdrawals.	1	Specify by using the appropriate jargon, for instance "application efficiency", defining the parameter	Wording
					2	Display the conceptual model used (and its complete references if retrieved from a specific model) with specifying in a prominent colour or another means of identification what is encompassed by supply efficiency	Pop up window
58	Scenario editor - Agriculture	Unclear understanding of how fallow influence water availability and soil moisture in the crop model	Usability	The importance of the kind of fallow type and how it influences soil quality and crop production is not obvious for non-specialists and may hinder their ability to consider and try scenarios using the fallow parameters	1	Display a conceptual model for the crop production model (with complete references if retrieved from an existing model) with a brief explanation about the model and the assumptions made to increase users	Pop up window

						understanding on how to parameterise fallow parameters	
					2	Provide a link to the guideline to access the crop model, its description, assumptions, and potential references (if extracted or adapted from a particular source)	New command
59	Scenario editor - Agriculture	Unclear whether the impact of a change in fallow practices on soil moisture and quality could be visible using a static model	Uncertainty	Practices such as favouring remnant vegetation could improve soil quality but takes more time than other fallow practices	1	In a table, provide a definition for the different fallow type and information regarding the expected time range for a fallow type to improve soil quality and productivity. Also, the table could display the expected ranges for the potential increase in crops' production, according to the type of fallow method used, to	Pop up window

						raise users' awareness about the potential interest of using different fallow type strategies.	
					2	Under scenario results/agriculture, provide users with a representation of changes in agriculture results in terms of yields, water productivity and benefits based on changes in fallow types. Results could be presented with a confidence interval associated with the time extent users are expected to observe the results.	New data

60	Scenario editor - Agriculture	Unclear whether the available crops in the menu are representative of the cultivated crops in a reach	Uncertainty	The crops do not account for orchards or fodders for instance, that could be highly produced in a basin, minimising the water demand for irrigated crops	1	Include orchards, other vegetables, and fodder crops to have a more representative set of crops to select	New entry
					2	Next to crops (under the crops interface), display in a prominent colour a warning message for users such as "orchards and fodder crops are not considered in the model for irrigated crops"	Wording
61	Scenario editor - Agriculture	Unclear whether users would understand how to consider cropping intensity	Usability	To consider the cultivation of the same crop more than once in a year, users have to select a crop of interest more than once, make sure that the planting dates do not superimpose and provide the sown area size for each planted crop. However, the process is not immediately intuitive	1	Provide a brief explanation of how to proceed to parameterise multiple crops planting in a year	Pop up window
					2	Provide a link to a tutorial and/or guidelines to ease learning	New command
62	Scenario editor - Agriculture	Unclear how the model estimates irrigated crop yields and water demand is working	Uncertainty	To be able to understand the outputs given by the model, users need to understand how the different parameters are	1	Provide users with a conceptual diagram and a brief explanation on how the model works, together with the	Pop up window

				linked and the assumptions made to compute yields, water productivity and benefits		complete references of the model if extracted or adapted from a source	
					2	Provide users with a link to a tutorial and/or a guideline describing the model, its assumptions and how to parameterise it.	New command
63	Scenario editor - Agriculture	Unclear whether an average value for the crop factor would effectively represent crops' water needs according to the growing stages and planting season	Uncertainty	According to the planting time, water needs could be increased or reduced, modifying yields, water demand and benefits	1	Precise the nature of Ky. For example, "Mean Ky value" to raise awareness about the meaning of the parameter and its aggregation of different crop factor values according to a crop growing stage	Wording
					2	Consider different Ky according to a crop growing stage in the model input parameters	New parameter
					3	Present results under agriculture with considering a confidence interval for	New data

						the water productivity, benefits and crop yields based on a crop lower and higher bond Ky	
64	Scenario editor - Agriculture	Unclear whether total crop production (rainfed and irrigation) would sustain the population demand for nutritious food (and health)	Uncertainty	Based on soil quality and seasonal changes, plant requirements for water and nutrients could reduce its growth and nutrition content	1	Precise that values consider the "maximum" nutrition or protein content to raise users awareness about potential fluctuations in that parameter value	Wording
					2	Improve the link between crop yields and nutrition with considering nutrition content as a new output under agriculture which values fluctuates according to crop yields for instance. This add would improve users' awareness about potential costs or additional benefits from different scenarios and options.	New command

65	Scenario editor - Agriculture	Unclear whether market price for crops will fluctuates in the future	Uncertainty	Changes in inflation rate and/or market demand and scale for market demand could change the benefits from crop productions and agricultural direct and indirect incomes	1	Precise the time validity for the displayed market price to raise users awareness when considering the benefits from agriculture. Moreover, precise if the value represents global market value or local one. For instance, replace "Value" by "current value (global scale)" or "2015 value (global scale)"(based on the year used for the input)	Wording
					2	Provide changes in benefits for different demand price elasticities in scenario results for the benefits from crop production, as a confidence interval for instance	New data

66	Scenario editor - Agriculture	Unclear whether new crops (e.g., GMO) will modify crop maturity (as well as nutrition, water demand, land coverage and market price)	Uncertainty	New crop technologies could be relevant to consider broader options and opportunities according to changing conditions. The current setting is not explicit in how users could assume evaluating the interests of changes in crop technology, nor about the range for credible values	1	Provide users with a link to guidelines or a table with potential crop technologies and their associated value range for growing time, maximum yields, nutrition, and price to help users consider other options and give them baseline value to use for scenario design	New command
67	Scenario editor - Agriculture	Unclear whether changes in irrigated agriculture technologies (i.e., crop technologies, application supply technologies) could change the maximum yield	Uncertainty	Different irrigation application technologies could influence the maximum yield. For instance, central pivot irrigation may increase the maximum yield compared to basin irrigation	1	Provide users with a table with the type of technological change (e.g., central pivot irrigation, transgenic maize) and the range for expected crop yields	Pop up window
					2	Provide users to a link to the guidelines in which an additional entry to the table with the expected range of yield for different irrigation system technologies is presented.	New command

					3	Provide results for crop yields, water demand and benefits with a confidence interval for instance	New data
68	Scenario editor - Agriculture	Unclear whether the crops identified under crop estimates are representative of current sown crops	Uncertainty	Users may not check the source for information regarding the model and may need a reminder	1	Provide users with a reminder sentence emphasising that the identified crop types may not be representatives of the ones cultivated. For instance, " crop types are derived from crop categories under the GFSAD' s model"	Wording
					2	Insert a warning logo (e.g., exclamation mark) next to crops, and put both the warning symbol and reference in a prominent colour to raise users awareness about the crop estimates' model	Visual

69	Scenario editor - Agriculture	Unclear whether crop estimates for the planting area (ha) are representative of the coverage of similar irrigated crops at the field level	Uncertainty	Users may not realise or understand the assumption made in BF for allocating planting areas for different crop categories in the GFSAD's model	1	Next to "area" under crop estimates provide users with a brief explanation about the assumptions made for allocating planting areas in BF	Pop up window
					2	Next to "area" under crop estimates provide users with a link to a guideline explaining BF assumptions when allocating planting areas	New command
					3	Next to "area" under crop estimates provide users with a link to a tutorial explaining BF assumptions when allocating planting areas and how to correct the planting area ratio for each irrigated crops categories if knowing the importance of one or more cultivated irrigated crops in a basin	New command

70	Scenario editor - Agriculture	Unclear whether the "area" under crop estimates and associated "planting area" are representative of the same parameter and correspond to either the net or gross planting area	Uncertainty	The "planting area" under crops appear to be the net planting area as users can change the time for planting. On the contrary, under "crop estimates" the area appears to be the average gross planting area for a year and, in that case, the reporting of values under "crop estimates" may overestimate the land coverage for a crop over its growing period	1	If there are differences between the two planting areas between the crop model and the crop estimates model, values should be readjusted so that estimates from the crop estimates model are properly reported under crops. For example, if multiple plantings are considered, a same crop should appear more than once, with different planting times and different areas (the sum of the areas being equal to the number under crop estimates)	New command
					2	Consider changing the name of "planting area" for "net planting area" under crops, and of "area" for "mean annual gross planting area" under crop estimates, if appropriate	Wording

71	Scenario editor - Agriculture	Unclear whether soils of different quality are accessible for irrigation developments	Uncertainty	Users may want to evaluate the potential for irrigation developments for food production on moderately and highly suitable soils and for energy production on marginally suitable and moderately suitable soils. However, there is no visibility regarding where these soils are located and if the values correspond to the net available soil area after considering other land uses or if they correspond to the gross land suitability area.	1	If the area corresponds to the net available area, replace "area" by "net available area". On the contrary, consider replacing "area" by "gross or total area"	Wording
					2	Provide users with a map with the location of the different land categories and the delineation of current land uses	Visual
					3	Add a supplementary column in the table in which the proportion available for agriculture developments is provided	New entry
72	Scenario editor - Agriculture	Unclear whether the areas provided under land suitability are representative of current values	Uncertainty	The model to estimate land suitability is based on temperatures and rainfalls. BF does not consider temperatures. It is uncertain if the values were computed or just extracted for countryside values from the source	1	Provide users with an explanation about the origin of the values (i.e. Computed or extracted from a source) to raise awareness about potential needs to check for the status, and the time extent for the values	Pop up window

					2	Change "area" for "country size area estimates (time extent) for instance, if appropriate	Wording
					3	Put a warning symbol next to area and emphasise the reference in a prominent colour	Visual
73	Scenario editor - Agriculture	Unclear what is meant by small storages	Missing information	OFS could be either used for domestic and livestock uses or for irrigation (mostly orchards). For the former, sizes are generally under 8 ML and for the latter over that value. If willing to consider only storages for irrigation, the minimum size should be provided for users to edit a baseline model (if existing OFS practices for irrigation in a basin)	1	Put under brackets the minimal size for OFS to guide users when identifying OFS for irrigation in a basin or for scenario design	Wording
74	Scenario editor - Agriculture	Unclear whether runoff harvesting, generally based on gravity, requires pumping to fill storages	Missing information	The model considers storage filling from surface water and from runoff harvesting. If pumping is not necessary for the latter, the sentence is confusing	1	Replace "These storages" by "Storages using surface water are filled (…)"	Wording

75	Scenario editor - Agriculture	Unclear which conditions are associated with OFS filled from surface water	Usability	Conditions needed to parameterise water inflow from surface water to OFS are not obvious	1	Add a title above the last four parameters to clarify which parameters are associated with OFS filled with surface water. For example, "Pumping conditions"	Wording
76	Scenario editor - Agriculture	Unclear whether the parameter is concerned by OFS total coverage in a reach or by the proportion of the runoff harvested	Usability	Users may be confused by the wording, especially if non-experts, as they could make a parallel with dams' catchment area	1	Replace "catchment area intercepted" by "runoff intercepted" for example	Wording
77	Scenario editor - Agriculture	Unclear what is meant by target storage	Usability	Users, especially non-expert, may not understand how to parameterise the parameter	1	Provide users with a brief explanation of what is meant by target storage. For example, " the proportion of the OFS level that should remain filled between cropping seasons"	Pop up window
78	Scenario editor - Agriculture	Unclear whether rules for pumping based on regulated flows only are representative of actual withdrawals and their impacts	Uncertainty	According to the context (and in general), water diverted for OFS is done from unregulated streams. Basing the model for OFS on regulated flows only may limit the visualisation	1	Add a title above the last four parameters to emphasise that only regulated flows are considered. For example, "Pumping conditions from regulated flows"	Wording

				of impacts from OFS in a basin	2	Add input parameters to define the "threshold to commence pumping from unregulated streams", the "Fixed rate of unregulated flow" and "the percentage above threshold that may be pumped"	New parameter
79	Scenario editor - Agriculture	Unclear whether the fixed rate of flow is associated to regulated streams or both regulated and unregulated streams	Missing information	The wording is not specified and may lead to confusion	1	Add "plus some fixed amount of regulated flow"	Wording
80	Scenario editor - Agriculture	Unclear whether the proportion of flow is relative to the total annual flow or based on low flow and/or high flow	Uncertainty	Users may be confused in deciding how to parameterise this parameter for scenario design	1	Precise the type of flow considered in the definition that appears when pointing the mouse on the entry frame	Pop up window
					2	Provide users with a link to guidelines or a tutorial in how to parameterise this parameter based on low flow, if appropriate	New command

81	Scenario editor - Agriculture	Unclear whether the proportion that could get pumped above threshold fluctuates with seasons	Uncertainty	There is no monthly changes associated with the proportion of water that could be diverted from surface water. The consideration of annual flows for the model also increases the risk of setting inappropriate flows that could hinder aquatic systems' health	1	Enable users to configure monthly changes in the proportion of flow withdrawn above threshold	New command
82	Scenario editor - Agriculture	Unclear understanding of the model logic for OFS	Usability	The model appears to be mostly based on filling OFS with surface waters when runoff harvesting could not sustain it. Hence, it seems not to consider OFS based on rainfall harvesting only.	1	Provide a conceptual model with a brief explanation and location for the different parameters, as well as references if designed based on existing sources	Pop up window
					2	Provide a link to the guide and/or tutorial where the model is explained	New command
83	Scenario editor - Demands	Unclear how population estimates for current and future population are computed	Uncertainty	There is no reference to the model used to compute current and future population estimates	1	Provide the complete references for the model used for population estimates at the bottom of the page	Wording

84	Scenario editor - Demands	Unclear whether the drinking water demand will be met	Uncertainty	Livestock growth and water demand is not considered in the model	1	Add livestock population, growth rates and mean daily demand per capita to present more realistic estimation of water demand for drinking and domestic uses	New parameter
85	Scenario editor - Demands	Unclear whether users will understand that they must choose to either parameterise the ratio or provide a mean annual water consumption	Risk of error	If parameterising both, the model will add both numbers	1	Place a "or" between the two options	Wording
86	Scenario editor - Demands	Unclear whether mean daily water demands per capita below 100 L/capita/day are not already representatives of limitations in the drinking supply to support the demand	Uncertainty	According to the WHO, a minimum of 100 L/capita/day is required to sustain minimum domestic water needs. When reporting values for their baseline scenario, users may not be aware of this minimum value for appropriate supply	1	Highlight in a prominent colour the box with a value under 100L/capita/day to raise user awareness	Visual
87	Scenario editor - Demands	Unclear whether only surface water supply or both groundwater and surface water supply are considered in the model	Risk of error	Users may accidentally consider the total water supply for domestic uses and not only the one	1	Remind users, above reach population, in a prominent colour, that "Only surface water withdrawals are	Visual

				associated with surface water		considered in the model"	
88	*Scenario editor - Demands*	*Unclear contribution for water supply between groundwater and surface water to domestic and industrial demands*	*Uncertainty*	*In some cases, industrial water demand could be mainly support by groundwater, reducing the impact of the industrial sector on surface waters. Also, it is unclear how groundwater withdrawals could impact surface water supply*	*1*	*Consideration of groundwater supply and linkage to surface water (current)*	*New parameter*
89	Scenario editor - Demands	Unclear whether the population have access to safe drinking supply	Uncertainty	The model is not considering the proportion of the population connected to the water supply network and the efficiency of the network. Both parameters could both reduced the demand for water supply and increase water demand as a function of the grid system efficiency	1	Consideration of drinking water connection to the grid system and the grid system efficiency	New parameter

90	Scenario editor - Transfers	Unclear whether users could parameterise monthly water transfers below 5 GL	Usability	The scale range is of 5GL which could limit users' ability to parameterise small water transfers	1	Provide users to a link to the guidelines with guidance in how to parameterise transfers using small monthly volumes	Pop up window
					2	Enable users to set values using 1 GL units instead of 5 GL ranges	New command
91	Scenario editor - Transfers	Unclear whether inter-basin transfers could be parameterised	Usability	Users may not be aware that they could transfer water outside a basin or inside a basin from another one	1	Provide users to a link to the guidelines with guidance in how to parameterise inter-basin water transfers	New command
92	Basinpedia - Model creation	Unclear whether the estimates for land uses represent current values	Uncertainty	Different sources may provide different land uses values that could confuse users	1	Provide "Additional reference(s) regarding land-use models" and list complete reference(s).	Wording
93	Scenario editor - Agriculture	Unclear whether users will realise they could design scenarios with improving or with different technologies' application efficiency values	Usability	Users may not be aware that they could access a table with a range of indicative values for different technologies	1	Display the table with the type of technologies and range of efficiencies	Pop up window
					2	Provide a link to the guideline to access the table and its values	New command

94	Scenario editor - Demands or under water transfers	Unclear whether current water supply will support demands	Uncertainty	Other water supply alternatives are not considered in the current interface limiting users' consideration of other option to reduce stress on water systems	1	Enable users to trial supply alternatives such a desalination plants, recycled water. In the context of the model, recycled water could be proposed as an alternative and set as a proportion of the water not consumed directly after withdrawals and not returned to surface water. A table with a range of values for the costs associated with different treatment plants, time for implementation and volumes that could be treated could be provided to ease users evaluation of the interest and feasibility of recycled water options. Users could additionally select one or more destinations for recycled water uses: industrial; domestic; agriculture	New parameter

95	Scenario results - run scenario	User may not be aware of the Rainfall-Runoff calibration was not completed	Usability	Users may not understand why they can't run scenarios due to incomplete calibration processes	1	Warning message alerting about incomplete calibration process and explanations for possible causes to investigate.	Pop up window
96	Scenario results - run scenario	The method used to generate data is not specified	Missing information	Lack of clarity related to the model to generate missing data	1	Link to information about the approach to generate missing data, including references	Pop up window
					2	Mention, next to the location of the component for data generation, of the name of the approach used and its reference	Wording
97	Scenario results - run scenario	To identify the status of different scenarios, different warning functions are provided without clear indication of their purpose, means of estimation and quality evaluation of the fitness of generated results	Missing information	Lack of clarity related to the role of the function based on the warning symbol	1	Brief explanation in a legend of the meaning for warning icons	Wording
					2	When hovering above the warning icons, appearance of a pop-up window clarifying their purposes	Pop up window
98	Scenario results - run scenario	The kind of information found with the download function in unclear	Missing information	There is no indication or ability to choose the type of information to download	1	Brief explanation next to the download thumbnail of what to expect	Wording

					2	When hovering above the download thumbnail, clarification of what can be downloaded	Pop up window
99	Scenario results - run scenario	Users may not understand the purpose of a symbol and use to guide their selection of scenarios to compare	Missing information	Some symbols are ambiguous as to their function	1	Clarification of the meaning for symbols while hovering above them	Pop up window
100	Scenario results - run scenario	Users may want to have an idea of the fitness of the model to generate missing data	Missing information	There is no clarity on the uncertainty around data estimated	1	Provide statistical estimates or uncertainty level indicative of the fitness of the model for generating data	New data
					2	When hovering above 'data generation', include a window to inform users about the quality of estimates and implications when interpreting results	Pop up window
					3	Use a traffic light approach to qualitatively indicate uncertainty levels (e.g., high-red, moderate-orange, low-green) for the estimates	Visual
101					1	Icon indicating progress	Visual

	Scenario results - run scenario	Users may want to have an idea of the time of the model to calculate missing data	Missing information	There is no clarity about the length of the process to generate data	2	Message about the expected duration for completing data generation	Pop up window
102	Scenario results - scenario comparison	The absence of mention of ecological objectives in the user interface (UI) and absence of clear visibility of this feature question the tool ability to represent ecological impacts	Missing information	There is no evidence the tool provides results about ecological impacts	1	Add next to scenario comparison, ecological impacts	Wording
					2	Include symbols associated with different tabs, reflecting different types of results. For example, a tree in green next to scenario comparison to suggest ecological indicators.	Visual
					3	Following run scenario, make a window appear providing an overview of scenario results and offering the possibility for a walkthrough of the different features provided	Pop up window
103	Scenario results - scenario comparison	The process to visualise ecological impacts is unclear	Usability	The process to set the comparative tool to evaluate ecological impacts is unclear	1	When selecting scenario comparison, a window appears with a brief overview of how scenario comparison	Pop up window

						could be used for evaluating ecological impacts. A walkthrough could be proposed in addition to the overview	
104	Scenario results - scenario comparison	Users may want to add notes about a scenario result or update a scenario information not only when comparing scenarios but also when analysing single scenarios	Usability	There is no clarity related to the potential to keep track of findings for different scenarios	1	Include a component for users to take notes and keep track of findings across evaluated scenarios	New entry
105	Scenario results - scenario comparison	The choice of colours may influence users' judgement and analysis	Risk of error	Some colours could be interpreted as providing trends or negative or positive impacts	1	Change for less subjective colours instead of green and red	Visual
106	Scenario results - scenario comparison	Users may want to have an overview of the results for all the scenarios	Missing information	The comparative function enables the comparison of only two scenarios at a time and there is no possibility to have access to a summary of all the results between different comparisons of scenarios	1	Allow users to compare more than two scenarios together as well as the option to consider the results for all tested scenarios	New command
107	Scenario results -	Users may not be aware of the assumption to estimate mean annual values in the tool	Missing information	The model used to estimate ecological impacts is not fully documented and not	1	Link to information about the indicator used, including references	Pop up window

	scenario comparison			all parameters were considered. Users may not be aware of assumptions made to use the indicator.	2	Mention, when selecting scenarios for using the indicator, the name of the approach used and its reference	Wording
108	Scenario results - whole of basin	Users may want to have any idea of the confidence levels around different computed values	Missing information	Some results only include averages and users may want to have an idea of the error or uncertainty around the numerical values.	1	Include statistical values such as the confidence interval or standard deviation	New data
					2	Use a traffic light approach to qualitatively indicate uncertainty levels (e.g., high-red, moderate-orange, low-green) for the estimates	Visual
109	Scenario results - whole of basin	User may want to have an idea of the means of estimation of the results	Missing information	Different estimates are provided to summarise results for the whole basin. Some values may build on changes in or use of specific types of indicators that requires documentation	1	Allow users to access information and key references about specific indicators. If modified, include the rationale for changes in an indicator, potential references with similar uses, and implications for interpreting the results.	Pop up window

110	Scenario results - scenario comparison	Unclear how mean annual values are estimated	Missing information	There is no information about the method and potential sampling approach to estimate average values	1	Clarify for specific indicators the use of specific sampling methods and implications for estimating average values and their interpretation	Pop up window
111	Scenario results - whole of basin	User may need to understand how population growth is considered when considering D&I water demands over a time period	Uncertainty	The tool provides estimates of population growth. However, there is no information as to whether these estimates are included in built -in models for estimating changes in domestic and industrial (D&I) water demands over time or not	1	Under scenario editor, clarify the purpose for population growth estimates and how they are considered in the model. Potentially, suggest solutions for using population growth estimates when running scenarios and analysis results	Pop up window
					2	Allow users to set population growth scenarios with the tool	New command
112	Scenario results - run scenario	Users may wonder if the speed to progress information and compute results is reflective or not of issues in task processing	Uncertainty	There is no indications about the reasons explaining the time for the tool to estimate results, and whether issues in parameterisation or	1	Message warning about network issues or incomplete parameterisation of compulsory parameters under the scenario editor	Pop up window

				network explain task processing issues			
113	Scenario results - whole of basin	Users may wonder if editions made under scenario results are adequately saved	Usability	There is no notifications ensuring users changes to scenarios have been effectively saved	1	Allow users to save manually changes with adding a message confirming saving	New command
114	Scenario results - whole of basin	Users may want to understand how to choose relevant and compatible climate datasets for exploring a basin in a specific country context	Uncertainty	There are no indications about how to select historical and climate datasets, that could be used for exploring past, current and future scenarios, and for specific geographical contexts.	1	Highlight in different colour or by adding a symbol for compatible datasets when setting the Rainfall-Runoff (RR) model	Visual
					2	By hovering over the datasets, provide a window with an overview of the dataset, key references, compatible datasets among available datasets and potential indications of relevance in specific contexts	Pop up window

115	Scenario results - whole of basin	Water uses are halved in climate change scenarios compared to the baseline one (historical datasets). Crop water requirements and yields being calculated based on ET values, users may need to understand potential assumptions made in the crop model under climate change scenarios	Uncertainty	There are no indications of assumptions made to evaluate crop yields under climate change scenarios.	1	When hovering about the results, a window appears providing potential assumptions for the estimation of crop water requirements under climate change and implications in terms of uncertainty around values and implications when interpreting results	Pop up window
116	Scenario results - water balance	There is no explanation regarding the means of calculation for GW recharge.	Uncertainty	There is no explanations about the Rainfall-Runoff model used and how it considers infiltration and estimations of groundwater (GW) recharge	1	When hovering about the results, a window appears providing information about the approach to estimate GW recharge values, reference and implications when interpreting results	Pop up window
117	Scenario results - water balance	In some cases, GW recharge is higher than irrigation which question how these two parameters are linked in the crop model.	Risk of error	The water balance summary provides some recharge values for GW higher than for irrigation water.	1	Above GW recharge and irrigation water, add a sentence about how models for estimating these variables are linked or not. If no relationships exist, ensure to highlight in	Wording

						bold or red the absence of connections	
118	Scenario results - water balance	Irrigation water returns is not considered in the water balance questioning the model assumptions regarding the exclusion of irrigation water returns.	Risk of error	There is no evidence of return flows from irrigation, even when considering irrigation systems with low water use efficiency.	1	When hovering above irrigation water, clarify in a window why return flows were not considered and implications when evaluating scenarios	Pop up window
119	Scenario results - water balance	Some results are expected to be identical between the scenario editor and the results. Differences could question the quality of the means to compute the estimated in the water balance	Risk of error	Comparisons of results in some parts of the Scenario Editor, that should be like the results in the scenario results, were different; suggesting potential errors.	1	Ensure consistency between models used to estimate similar parameters	New parameter
120	Scenario results - water balance	Values estimated manually could differ from the ones provided by the model and question the method used to compute them	Risk of error	When calculating manually some of the indicators, such as domestic water uses, results were different from the ones estimated by the model, suggesting potential errors.	1	Ensure consistency between models used to estimate similar parameters	New parameter

121	Scenario results - water balance	Some values may not be presented with the appropriate units when considering similar outputs in other pages of the UI.	Risk of error	The units were not provided in some cases, limiting the proper interpretation of the numerical values provided	1	Include international units for all numerical values	New data
122	Scenario results - water balance	The logic of the conceptual model for the tool needs to be reflected in the water balance and users need to access the model structure	Risk of error	Results from the Sankey diagram for the water balance were different from the numerical ones in the summary table	1	Ensure consistency between representations of similar results	New parameter
123	Scenario results - flow metrics	Users may not realise the process to be able to compare changes in flow regimes between two scenarios	Missing information	The process to compare scenarios is unclear to be able to access results about different flows metrics.	1	Clarify next to scenario comparison the order and steps for selecting scenarios to evaluate the impacts of climate and societal factors on flow regimes and impacts for ecological systems	Wording
					2	Allow users to follow decide whether they want the assistance of a walkthrough or not	Pop up window
124	Scenario results - flow metrics	No completed information is provided about the source for the data displayed	Missing information	There is no information about the model used to evaluate ecological impacts based on flows.	1	On the page providing model results, include the name, a brief description and the reference(s) for the indicator used.	Wording

					2	On the page providing model results, include a link to information to the indicator used, with a window indicating its name, purpose, main references	Pop up window
125	Scenario results - flow metrics	It is unclear whether the use of absolute values rather the relative ones would help users identify the type of impacts on flow regimes between two compared scenarios	Uncertainty	How to interpret the values for the ecological impact models were unclear	1	On the page with the indicator results, clarify in a sentence how to interpret the results and cautions around factors not considered by the indicator.	Wording
126	Scenario results - flow metrics	Some users may not realise they should compare for pre- and post-development scenarios, scenarios with different timeframes.	Missing information	The process for parameterising scenarios to be compared to evaluate changes in flow metrics and their implications was unclear	1	Under scenario comparison, provide a brief overview of how to set up scenarios to be compared and potential logical rules	Wording
					2	When opening the page with the setting for scenario comparison to evaluate impacts on flow regimes, a dialogue box could provide a brief overview of the process to set up scenarios and purpose,	Pop up window

						and suggest links to a walkthrough or tutorial with examples of good and bad settings	
127	Scenario results - flow metrics	The IHA index identifies different groups reflective of different assumptions for habitat and physiological processes impacts as a result of changes in flow regimes. It is unclear how aggregating these values remain informative for users and provides a good representation of ecological impacts in the tool	Missing information	There is no information about how to interpret the different indicators used	1	Underneath the table with the results, provide a brief overview of the type of results provided and how to interpret them.	Wording
					2	Underneath the table, provide a link to information about the results provided, opening a dialogue box with explanations about the indicators provided, their purposes and meanings	Pop up window

128	Scenario results - flow metrics	Only two groups over the five main categories descriptive of different ecological impacts associated with changes in flow regimes are considered, questioning the index representation of ecological impacts.	Uncertainty	There is no certainty as whether the information provided is sufficient for understanding impacts on ecological systems	1	Next to the results, provide a link to the indicator and include a brief explanation for simplifications in the choice of monitored variables, clarify missing ones, and implications when interpreting the results provided	Pop up window
129	Scenario results - flow metrics	The IHA index consider mean values and dispersion values to display and account for the variability of flows and associated ecological risks. Users may want to consider the range around mean values too.	Uncertainty	Only averages were provided, limiting understanding about fluctuations around the means and implications for considering ecological impacts	1	Include dispersion values in addition to average ones to account for variability in flow regimes	New data
					2	Include a link to a dialogue box, clarifying assumptions for considering some average values instead of the whole indicator and different variables and statistical values, and a caution message when interpreting results. For the latter, clarify how to interpret the results.	Pop up window

130	Scenario results - flow metrics	Users may want to have an idea of satisficing values or threshold for different flow values influencing aquatic systems' health	Missing information	Are the values indicative of ecological degradations	1	With information associated with the indicator, provide an example of what could be an acceptable value, under specific conditions, with a reference for the example.	Pop up window
					2	Clarify, in a sentence, above the table with the results, a choice of threshold and a link to a dialogue box with more information about the assumptions and references for setting rules. Using a traffic light approach, highlight with colours reflective of different risk levels acceptable (green), limited (orange) and unacceptable (red) values	Visual
					3	Allow users to set a threshold for acceptable values	New parameter

131	Scenario results - reach hydrology	Some users may not notice differences in units and could be confused by the values displayed in the download files	Usability	Units displayed in the user interface and with downloaded timeseries were different	1	Ensure consistency in units between timeseries values in figures and in downloaded tables	New data
132	Scenario results - reach hydrology	Some users may get confused using labels rather than corresponding names or reach number as provided in the scenario editor among others	Usability	Labels for the reaches were different in the results compared to the ones set by users when setting their scenarios	1	Ensuring consistency in naming between settings made in the scenario editor and downloaded files	Wording
133	Scenario results - reach hydrology	There is no clarity as to what some results displayed aim at.	Usability	Some figures are provided without headings, limiting understanding about their purposes	1	Add headings for tables and figures where relevant	Wording
134	Scenario results-reach hydrology	Units are absent from some figures, increasing effort to identify them from available datasets and existing information about built-in models	Usability	Some figures are provided without units.	1	Clarify any units for variables displayed in tables and figures.	Wording

135	Scenario results - reach hydrology	Monthly inflows in the storage could help evaluate when it would fail to provide flood protection for instance. Users may want to access this parameter to identify multipurpose storage failure in enduring flood protection for downstream populations and to reduce infrastructural and economic damages. It could also be used for assessing limitations for navigation purposes.	Uncertainty	Users may need to consider monthly inflows in storages to evaluate the extent to which they could remain effective under different climate and water uses or development scenarios	1	Allow users to access timeseries for 'effective' monthly inflows in reservoirs when downloading timeseries	New entry
136	Scenario results - reach hydrology	In addition to storage capacity over time and/or storage outflows, users may want to have an idea of acceptable supply for different water uses and users	Usability	Highlighting conditions for which water storages fail to ensure water security for D&I or irrigation in timeseries could ease evaluation of storage reliability and effectiveness	1	Next to the heading for storage reliability, provide a link to access information about different reliability thresholds, their context of applications, relevant references, and implications when considering timeseries data and evaluating storage reliability	Pop up window

					2	Enable users to set different reliability thresholds for storages	New parameter
137	Scenario results - reach hydrology	Effort to understand and relabel column headings in downloadable timeseries to keep track of reaches and their associated values for estimated indicators	Usability	When downloading timeseries, columns are labelled with numbers instead of the name for the reaches as set in the scenario editors	1	Ensure consistency in naming between settings made in the scenario editor and the headings with downloaded files	Wording
138	Scenario results - reach hydrology	The length of the numerical labels masks the name of the variable estimated	Usability	When downloading timeseries, a lengthy list of numbers may mask the name of the estimated variables in the column headings	1	Remove numbers to directly provide the name of the variable monitored and its units	Wording
139	Scenario results - reach hydrology	Some timeseries data are provided for download purposes, with similar data but different names	Usability	Similar tables with different names appear repetitive and confusing	1	Remove repetitive timeseries datasets to avoid confusing users	New entry
140	Scenario results - reach hydrology	Additional information could be inferred from the flow duration curves (FDC), and users may be interested in assumptions that could be deduced to identify potential alternative indications of a system performance or the robustness of different actions	Usability	Can information/additional indicators about a system performance could be deduced from the flow duration curves (FDC)	1	Provide a link with information on how to use and interpret FDC with relevant references	Pop up window

141	Scenario results - agriculture	Some users may like to easily access the values of some indicators	Usability	The user needs to hover its cursor above pie charts and wait a moment before accessing some numerical values for key indicators	1	Directly add data values on or next to relevant sections of pie charts	Visual
					2	Clarify in a sentence above pie charts how to access the results, with a warning that results may take a few seconds for appearing	Wording
142	Scenario results - agriculture	The references are incomplete.	Missing information	Information about some indicators, their purpose and means of estimation are missing, that could reduce interpretation of the results	1	Provide a link next to the indicators to open a dialogue box with information about its purpose, references, and how to interpret it	Pop up window
143	Scenario results - agriculture	Unacceptable thresholds for water use efficiency indicators are not documented	Missing information	Water productivity is used for evaluating water use efficiency. However, there is no documentation about potential threshold values indicating acceptable results and benefits of different irrigation systems	1	While providing information about the indicator, clarify what acceptable values are, according to the irrigation system used. Add key references for thresholds.	Pop up window
					2	Highlight in red for example unacceptable values, based on the choice of irrigated system	Visual

					3	While providing information about the indicator, if related to using other indicators such as flow regimes, clarify how the contribution of irrigation systems could be evaluate using other indicators	Pop up window
144	Scenario results - agriculture	Changes in price according to the demand is not considered in the model	Uncertainty	There is no direct mechanisms or indications of how to set crop price to account for changes in market demands for crop production over time	1	Under scenario editor, highlight under crop settings how to set crop prices for scenario evaluation by clarifying in a sentence the location of the parameter	Wording
					2	Include a tab with access to crop prices, with a list of suggested values according to crop types	New parameter
					3	When selecting a crop type, directly link crop price with existing databased with crop prices for the model to	New entry

						directly account for existing estimates	
145	Scenario results - whole of basin	To evaluate the robustness of measures, users may want to evaluate the costs and benefits of different actions against different exogenous uncertainties	Missing information	Aside for incomes from crop yields, there are limited indicators of costs and other benefits from water uses, that may reduce users' ability to evaluate the net benefits from different developments or actions under climate and other societal changes (e.g., migration, population growth)	1	Allow users to customise the tool to set costs for agricultural operations when setting the crop model, and additional benefits. Costs and benefits could be linked to existing features when setting scenarios such as water pricing per ML or capital and operational costs for irrigation systems	New parameter
					2	When summarising results for the whole basin and agriculture, include costs or consider net benefits values from irrigation	New data
146	Scenario results - agriculture	Information in downloadable files need to be consistent with the one provided in the UI	Usability	Headings from downloaded timeseries of crop yields consist of numbers. There is no correspondence with	1	Ensure consistency in naming between settings made in the scenario	Wording

				reaches as set in the Scenario editor		editor and the headings with downloaded files	
147	Scenario results - agriculture	The legend of some figure may imply that the figure is representative of water use at a reach level and not for the whole basin	Risk of error	Some legends do not provide the right information. For example, the name of a single reach was used to display mean timeseries water uses for the whole basin.	1	Ensure consistency in naming between legends and represented features in figures	Wording
148	Scenario results - flow metrics	The information is provided on an annual basis that may mask seasonal variations. The provision of annual 1-day min/max is not sufficient to gain insight about seasonal variations	Missing information	Absence of seasonal variations may mask ecological impacts.	1	Allow users to access seasonal values in addition to mean values	New data
149	Scenario results - indicators	Some users may not be aware of the relationships between different parameters to estimate some indicator values	Usability	There is no evidence of relationships between models	1	Provide a link under the scenario editor and summary page for the whole basin in scenario results to the conceptual model displaying relationships between built-in models. This link could open a dialogue box with an overview of the	Pop up window

						relationship between built-in models and implications for interpreting results and/or link to the documentation.	
150	Scenario results - indicators	Threshold reliability values are based on a proportion considered acceptable in arid and semi-arid context for irrigation. This value could be higher in more temperate climatic countries and/or for drinking water supply	Missing information	Value for storage reliability is based on a threshold value for irrigation. Other values exist for considering storage reliability for uses beyond irrigation, and that may be more constraining. For example, 90% reliability for drinking supply	1	Next to the sentence providing the threshold value for storage reliability, include a warning for considering storage reliability values	Wording
					2	Allow users to set reliability values according to their contexts	New parameter
151	Scenario results - indicators	Values, according to the temporal scale considered (e.g., annual) could mask seasonal failure of the storage and could be of critical importance to evaluate over irrigated crops planting season.	Missing information	Crop growth and yields may vary with planting and harvesting time and the planting area and soil quality. Demands in water may vary and annual estimates of storage	1	Next to storage reliability, add a warning that values may mask potential failures and refer to downloadable timeseries datasets for users to identify the seasonal	Wording

				reliability may mask seasonal failures		frequency of failure for storages	
					2	Add an estimate of the seasonal reliability of storages for clarifying the extent to which storages remain effective under different futures and water development scenarios	New data
152	Scenario results - gauges	There is no means to consider the performance of the calibration for the RR model in ungauged basins and for climate change datasets	Uncertainty	Gauges were added to evaluate the calibration of the rainfall-runoff model and estimate different hydrological indicators. For unregulated rivers and climate change datasets, no gauges could be used to evaluate the quality of model calibration.	1	Add a small warning about the quality of estimates, based on the type of water system considered and state of the monitoring season	Wording
153	Scenario results - gauges	Users may want to have an explanation regarding the choice of these indicators	Missing information	Information is needed about the choice of statistical indicators for	1	When hovering above the indicator, provide a brief overview of how to interpret values	Pop up window

				evaluating model calibration	2	Highlight in red for example unacceptable values.	Visual
154	Scenario results - gauges	Users may need to have an explanation regarding how the RR model could be calibrated in the absence of gauge stations	Missing information	Assumptions for calibrating the RR model in the absence of data from gauge stations in regulated water need to be clarified.	1	For clarity, provide a link to a dialogue box explaining how the RR could be calibrated in the absence of available data, under run scenario and gauges	Pop up window
155	Scenario results - hydropower	Users may want to have access to timeseries values to identify potential failure in hydropower production	Usability	Hydropower timeseries are not available	1	Add timeseries datasets for hydropower generation.	New data
156	Scenario results - hydropower	The change in unit intervals could confuse users	Usability	Timeseries for hydropower generation could present different unit intervals (e.g., 50,000-unit intervals and 100,000-unit intervals)	1	Ensure consistency in interval units for figures with hydropower generation values	Visual
					2	Allow users to change the unit range, according to their visualisation needs	New parameter
157	Scenario results - hydropower	Users may not be aware of how hydropower generation values are computed.	Missing information	There is no information about the model used to estimate hydropower generation.	1	Provide a link to the model used to estimate hydropower values and its reference	Pop up window

Table D.2. Identified issues and solutions from the expert review.

Different issues were formulated by the experts and, in some instances, some suggestions of solutions and priority levels, explaining blanks in the table.

Issue label	Issues	Why?	Importance to fix (priority level)	Solution label	Solution
1	Unclear precision of the areas of applications and associated intended audience in the tool homepage	Users may not be aware that the tool could be fitted for their purpose	must do		
2	Unclear whether the zoom function ease users' identification and visualisation of their basin of interest when using the map for creating a basin model in the Basinpedia	Users may want to zoom in when exploring the map in the Basinpedia to create their basin model, but the zoom function may increase their burden to identify a basin of interest		1	Provide a zoom scale with a maximum zoom level to ease and limit users ability to zoom in on the maps
3	Unclear whether the search function ease users' identification of their basin of interest in the Basinpedia	Users may use the function and be directed to the wrong basin or not be directed at all to their basin of interest	must do	1	Improve the search function to ease user experience and identification of a basin
4	Unclear whether you understand how to deal with bugs in the software	Users may not have the patience to try to identify means to solve some of the issues faced in the interface	nice to have	1	Provide data without errors

5	Unclear whether users would understand how to use the levels of resolution in the Basinpedia to identify their basin of interest	Users could be confused by the aim of the high level of resolution function and how to use it	nice to have	1	Provide a more explicit name to the function instead of 'level of resolution'
			nice to have	2	Provide an explanation of the high level of resolution function and the process to use it
		Users may be confused in identifying the process to use different levels of resolution to identify a basin of interest, which could reduce the usability of the tool.	must do	3	Provide users with adequate information and guide through a support package including a user manual, guided tutorials and so on.
			must do	4	When using the search function, automatically change the level of resolution to ease users identification of a basin of interest
6	Unclear whether the country name when selecting a basin in the list provided with the 'search' function under Basinpedia is sufficient to direct users to their basin of interest	The name of the country may be insufficient to direct users to their basin of interest, and they may need additional information to avoid selecting a wrong basin	must do, (nice to have)	1	Use a second level of identification such as a state name to ensure the proper selection of a basin. It is important for managers, students, and teachers to be able to associate information with a name they are familiar with.

		In most cases, the labelling of a basin and main district is wrong and some users may not be aware of potentially choosing a wrong basin	nice to have	2	Correct the labelling error in the database.
7	Unclear whether users have a visualisation of their basin of interest	After selecting a basin under the Basinpedia, there is no mention of the name of the basin anywhere on the page and users may not know beforehand the shape and location of a basin they are looking for.	must do		
		There is no mention of the proper name of a basin in most cases	must do	1	Enable users to click on a basin and access its name.
8	Unclear whether users could cross-validated the location of their basin of interest	There is no apparent names of towns, roads, or other location means making uncertain the identification of a basin of interest		1	Make the places names and main towns names appear, not when selecting the layer of information, but as a default, to be able to locate a basin of interest
9	Unclear whether the platform could welcome additional data inputs	Researchers may want to know if they could contribute to the global database by importing data, currently or in the future		1	Provide a line in the homepage of the tool to clarify that users could contribute to the database of the tool by providing their input data.
			nice to have	2	Enable users to generate their own climate sequence

		Researchers may use their own database and field data and may want to use them when working with a specific basin. Similarly, they may want to use native crops that are dominantly cultivated in their basin. Also, users could want to upload gauge station datasets when manually selecting points to design a basin reaches such as near dam locations	must do	3	Enable users to use their own database and import their own data in the tool
		Some users may like to edit their own crops without overwriting existing one when using 'action' under 'crops' in the scenario editor		4	Enable users to create and add their own crops to the list
10	Unclear references for the stress indicators in the Basinpedia	Especially for researchers and water resources managers, more straightforward and detailed references would help understand the nature, objectives, coverage and applicability of the stress indicators	nice to have	1	Provide the full references with each associated indicator
			nice to have	2	Provide a link to the references

11	Unclear whether users would understand how to close the window associated with global per capita water uses for domestic purposes under 'demands' in the scenario editor	The size of computer screens may be too small to be able to find the close button at the bottom of the pop-up window and may frustrate users that may not find how to close it			
			nice to have	1	Ease users' ability to close the pop-up window displaying global water use per capita estimates
12	Unclear whether the focus of the tool is water availability or broader	Users may think that, as a high-level water resources assessment tool it could cover broader aspects such as water quality		1	Clarify the coverage of the tool to avoid some users' misunderstanding of the tool
13	Unclear whether the tool could be broadly used for water resources assessment	Some basins could be water-rich, and their main issue would be water quality and the impacts on ecosystems. The tool is self-limiting and reduces the potential for more users' interaction due to the absence of coverage of water quality	must do	1	In the Basinpedia, include a water quality indicator and some sort of basic indicator for the environment associated with water quality
			nice to have	2	Consider the incorporation of water quality in the tool
14	Unclear whether, in the Basinpedia, you need the charts to describe land uses	Some users may find the reading of the charts complicated	nice to have	1	Replace the different charts with a single pie chart summarising land use information

15	Unclear scale and complexity' levels of the tool	Users may feel confused by the inconsistency regarding the levels and spatial scales of the information in the tool. Some spatial scale information to parameter or provided is broad and some other, like the soil type, is very specific and point scale.			
16	Unclear whether users could select a soil type	Most users may not be able to select a proper soil type as it could easily be a mix of these soils for different locations in a reach. Moreover, they could feel confused in the way of setting the 'soil type' parameter.	nice to have	1	If you are talking about an area of the soil in a reach, change the wording and input parameter to "percentage of dominant soil"
			must do	2	Change 'soil type' for "dominant soil type" to ease understanding
			nice to have	3	Change 'soil type' for "proportion of dominant soil types" with allowing users to provide the respective proportions of the 3 main soil types in a reach
		Some users may use the default setting thinking that it is representative of the soil type		4	Provide users with a default setting representing the most cultivated soil type found in agricultural areas globally (i.e., a global average)

17	Unclear whether users could find the information to parameterise soil type and soil moisture parameters	Some users may not know where to find the information to parameterise the inputs for soil type and soil moisture, which could prevent the effective exploration of scenarios of interest and impact the credibility and salience of the model outputs			
18	Unclear how the model is functioning and calculating estimates	Some users may perceive the model as a complete 'black box' as there is no transparency about its structure and means of calculation of the different parameters	must do	1	Provide information about the model means of functioning and a conceptual diagram about the model to improve the credibility and trust in the model.

			must do	2	For the conceptual diagram (to be provided on the tool as the quick start guide and the user manual), it could represent what does a single iteration of the model look like and describe how things run. It could be presented in a pop-up window under the results too, in the water balance, with instead of the Sankey diagram, a presentation of the conceptual model at different time steps and inform users about how things change, for example. The idea is to communicate how the model works and not its purpose
		Some users may not understand how the values provided, both in the input data and output results, are calculated and/or against which datasets they are calibrated to.	must do	3	Provide users with adequate information and guide through a support package including a user manual, guided tutorials and so on.

			must do	4	Document the different models and their means of calculation of the different parameters to ensure that the users could evaluate if a model is fitted for their research purpose or not. More generally, make sure that the technical documentation will cover to tool functionalities
		Some users may not understand how the OFS model is working and linked with crop irrigation		5	Clarify how water availability for irrigation is defined in the tool and the linkages between storages and SW irrigation on the one hand and OFS irrigation on the other hand
		Some users may not understand why indicators under flow metrics are expressed in absolute values instead of relative ones	nice to have	6	Be explicit about the assumptions and the type of values displayed to users for the indicators in the flow metric function
		Some users may not understand how the storages are operated under the tool	must do	7	Provide users with the rules made to operate the storages in the tool
				8	Change 'environmental flows' under the scenario editor for 'storage operations' to have more control about a dam's operation rules

			nice to have	9	Explicitly mention or enable users to select a command as "if the level is too low, the dam has to release more water" to enable user to have a simple control of operation rules for the dams
			nice to have	10	Enable users to set basic operation rules for the dam such as a parameter with an annual value that the dam can release with the time until when this value prevail and an annual value for the other years
		Some users may not understand how GW recharge in the water balance is calculated.	must do	11	Provide users with transparency about how the GW recharge is calculated in the model in the documentation
		Some users may want to understand and see how the different models in the tool interact and influence the outputs. Case of the change in land uses and the change in RR.		12	Provide users with information regarding how the different models interact with each other's, the assumptions made in BF, and how changes in a model could influence the other ones
19	Unclear whether users will understand how to choose a climate scenario	Some users may be confused when choosing different climate scenario as they may not understand the assumptions associated with them	must do	1	Make explicit to the users what are the climate scenario models about and the implications for choosing them

			must do	2	Provide users with information about climate change scenarios in the documentation as well as a summary of the different scenarios in the interface to reduce the burden to go through the literature
		Some users may want to have indications of the categories associated with different climate change scenarios and indications of their respective assumption. For example, if a scenario is associated with drier conditions or not with respect to a basin in a specific country		3	Categorise scenarios according to their impacts on climate and water resources for a basin with a country to ease users understanding of what the expected climate changes would be associated with a scenario.
20	Unclear whether users would understand how to parameterise and analyse the parameters provided by the model	Some users may be confused when choosing visualising, parameterising, or analysing the parameters presented by the tool as they may not understand the assumptions associated with them and how the models beneath them are working.	must do	1	Make explicit to the users what are the parameters presented in BF are as well as their underlying models, and the implications for choosing or parameterising them, as well as how to interpret them.

				2	Ensure that the elements described in the quick start guide could be found in the UI. For instance, by sliding their mouse over a parameter and/or component, a pop up window with a small explanation of the parameter or component would appear with defining the parameter and guiding users in how to edit or interpret it
		Some users may not understand how to calibrate scenarios and/or compare scenarios in the results. Case of the RR model.	must do	3	In the documentation, provide users with step-by-step guidelines of how to calibrate the RR function as well as use the different functions in the BF tool
			must do, nice to have	4	Provide a better user support package as for online help and tutorials showing, step-by-step how to set a model/scenario, run it and use functions such as the scenario comparison tool.
		Some users may need guidance and clear steps and pictures to understand how to create a basin model and calibrate scenarios	must do, nice to have	5	Having an example of model as a default under the tool with clear step-by-step guidance and explanations, and also a step-by-step manual with pictures explaining the example.

		Some users may not find existing functionalities in the tool, such as the planting date input parameter to set multiple planting time for crops, which may reduce the usability of the tool	nice to have	6	Provide more complete information about the different parameters and how to edit them in the quick-start guide. Ensure that pictures are available to illustrate each step and facilitate users interaction with the tool
			must do	7	Ensure that the technical documentation would explain precisely how to parameterise and use the tool
		Some users may want to subdivide a basin into reaches manually, selecting points on the map at the location of gauge stations	must do	8	Correct usability issues by enabling users to set splitting points (for the manual determination of reaches under the Basinpedia) at the location of gauge stations on the map
		Some users may want to re-name their scenario or the reaches and may not understand how to proceed	must do	9	Enable users to change the name of their scenario more easily, potentially with enabling changes at more than one place

		Some users may not understand the meaning of the different parameters displayed in the interface and how to edit or interpret them. Case for the GW aquifers categories under the Basinpedia where users would need additional information about the meaning and implications for recharge and extractions of the different structures.	nice to have	10	When making a right click on a parameter, users could access information about the parameter meaning and means of calibration
21	Unclear whether users could access the publications referenced in the tool about the climate change scenarios	Some users may not be able to access the publications, limiting the transparency of the tool	nice to have	1	Create a 'briefing section' in which the information about the climate change scenario could be summarised and the implications of selecting them. This section could include a function to download the publications associated with the climate scenarios too.
			nice to have	2	Associated with solution 1, ensure that a support team is in place to help with the selection of climate scenarios
22	Unclear whether users could be prevented from building inconsistent scenarios	Some users may try to mix different and inconsistent datasets for the rainfall and evapotranspiration when selecting	nice to have	1	Provide a warning to users to avoid that they try to select inconsistent scenarios

		climate change and/or historical climate datasets			
23	Unclear whether the tool provides enough management options	Users may want to explore more specifically some management and policy options that proposed in the tool	nice to have	1	Water trading options, when considering irrigation water management, could be useful to consider, particularly to reflect some existing context
24	Unclear whether users would understand how to evaluate the fitness of the climate models with the gauge stations data in a basin	Users may not understand how to see the values quantifying the fitness of the chosen climate models with observed data under scenario results, 'gauges'.	nice to have	1	Provide an alert message that could say "Please, hit the gauge" for example to be able to see the model fitness performance values
25	Unclear whether users would understand that some of the default values are not considered by the tool when computing the results	Users may think that, because default values are provided for some inputs, they would be automatically considered by the tool and visible under scenario results	must do	1	Develop a more detailed guide than the quick start guide with information about how to set different scenarios and implications of the choice of different scenario settings.
				2	Consider the default values when computing the results for users to consider as a baseline, without involving any action from the user side

26	Unclear whether users would be aware of the impact of changes for agriculture when provided with average values over a time period	Some users may not be aware or make sense of the values and may require comparing the impacts of different agriculture scenarios to a baseline to visualise critical changes	must do	1	Enable users to compare and visualise changes with all the agricultural indicator values.
27	Unclear whether the tool enable users to more generally compare different outputs from different scenarios	Users may want to compare the change of different indicators and parameters in the tool, and not only the ones from the water balance.	must do, nice to have	1	Enable users to compare results more broadly between scenarios to improve the interest in the tool and reduce users' manual recording of the results.
28	Unclear whether users would be aware of the location of potential sources of uncertainty	Users may not be aware of the uncertainty around some inputs and associated outputs	must do	1	Documenting key sources of uncertainties with the model structure could increase user awareness about the location of uncertainties within the tool and because it is becoming more of a standard among managers and in people minds
			must do	2	Provide, instead of average values or in addition with them, uncertainty range and/or error bounds for example to raise user awareness about the uncertainty associated with the results

			must do	3	Provide some indication of uncertainty in the calibrated parameter values (e.g. range, confidence bound) with an explanation of the implication on the model outputs
			nice to have	4	Provide a sentence, at least, informing users that the numbers displayed are not 100% sure. This sentence should be visible in the interface and in the documentation, including the climate change scenarios
			nice to have	5	Provide graphs of uncertainties and options to change the risk of uncertainties as well together with the explanations of the implication of choices (in the UI and/or the documentation)
			nice to have	6	Provide the outputs with a traffic light system to inform users about the confidence and reliability of the result. For example, 'green' for quite reliable, 'yellow' for some information known, and 'red' too little information.

			must have	7	Enable users to visualise the impact of changes for each outcome for the whole basin and each reaches (as for the BWS index) on a map to ease the visualisation of impacts and support discussions with stakeholders
29	Unclear whether the sensitivity of the parameters is documented	Users may want to have an idea of the sensitivity of the results	must do	1	Documenting the sensitivity of the parameters is important because it is becoming more of a standard among managers and in people minds
			must do	2	Create some kind of marker under scenario calibration such as "sensitivity parameters" to enable people to visualise how the results would change when trying different scenarios.
30	Unclear whether users have some awareness that GW and GW-SW interactions are not modelled in the tool	Users may not be fully aware that GW is not considered in the tool. What the tool is providing or not should be made explicit	must do	1	Clarify how GW is considered in the using a sentence such as "this reach as a high GW-SW interaction, but GW is not considered in the tool at the moment, therefore the uncertainties in the output actually are …"

		Users may not realise that the absence of consideration of GW abstractions and their impacts on SW and GW related ecosystems could made the evaluation of water scarcity in a basin by the tool unrealistic	nice to have	2	Include GW dataset such as GRACE and a model that could interact with GRACE, could provide additional data from bores and be able to link paths with SW and inform BF
31	Unclear whether users could easily see the search function in the Basinpedia or download functions, among others	Users may not be able to visualise the search bar in the tool due to the visibility of the functions	nice to have	1	Provide support to help users' navigation with the tool and identification of functions that may be uneasy to see immediately
			nice to have	2	Locate the download button in an easier to visualise place and put the button in a prominent colour, for example, to ease its visualisation
			nice to have	3	Make sure that, when scrolling up, the banner in the Basinpedia is not hiding the 'search' function. The search function should remain visible to users
32	Unclear time for processing the information and locate a basin for high levels of resolution under the Basinpedia	Users may found the time of processing burdensome, which could reduce the usability and the credibility of the tool in terms of easing use.	nice to have	1	Provide users with some indication of the time to identify a basin of interest, particularly when using high levels of resolution

			must have	2	Warn users of the time to process the information using a sentence or flag such as "This is a big job, asking a lot from your computer, are you sure you want to proceed?"
33	Unclear whether users would know the nature and/or have access to the full references of the models and datasets used	Users may want to know what model they are using to calibrate a model and have access to some information about them to understand how they are working and potentially evaluate their fitness for the purpose of their research	must do	1	Provide users with the metadata and associated references of the models and datasets used
		Users may not realise where are located the different datasets in the tool			
		Some users may find going through the literature burdensome	nice to have	2	Provide users with a summary of the references explaining a model or a dataset
		Some users may want to have more information about the different datasets in the tool	nice to have	3	Provide users with a small description of the available datasets in the tool as well as indication of fitness according to the tasks to perform. It could be done by making a dialogue box appear when scrolling the mouse over a dataset

34	Unclear whether users would be ascertained of the model processing and saving their scenario calibration adequately	Users may be unsure that their scenario calibration has been appropriately processed and saved by the model	must do	1	Ensure that the model correctly save the edited inputs and is stable
35	Unclear whether users would understand the nature and meaning of the numerical values they get or have to edit in the absence of visible units	Users may not understand the nature of the values displayed or how to enter inputs adequately			
36	Unclear whether users could diagnose errors or inconsistencies with the provided RR data	Some results or data provided by the software could be far from realistic and some users may not be able to realise that issue	nice to have	1	Implement a cross-check function to weight whether the computed values are realistic or not. This cross-check could be the runoff coefficient value associated with recommended values. As for model create, a message could be added with these cross-checks allowing the user to knowingly process or change the parameters.
			nice to have	2	Have additional global datasets as cross-checks, to compare the GR4J computed monthly values to other datasets and their fitness

37	Unclear what users would identify as indicators in the tool	Some users may not be aware of the different types of indicators in the interface and/or may think they are only provided in the results under the 'indicators' tab.			
38	Unclear relationships with the BWS index parameters	Users may not be aware of the parameters in the water balance influencing the calculation of the index values, which could lead to misinterpretations of the index due to poor calibration of the scenario			
39	Unclear whether inter-basin water transfers may impact water scarcity in other basins	Users could see the benefits from water transferred in their basin but not the impacts on the basin where the water has been transferred from. There is also a timing question with the water transfers and water scarcity impacts in the source basin and later in the receiving basin that is not visible to users			

40	Unclear whether the estimated recharge rate for GW in a basin is a good indicator a water availability	There is a tendency, for simplification purposes, to think that the estimated recharge is the amount of water that could be extracted from GW. However, this representation could mislead users and poorly acknowledge the complexity and lack of knowledge associated with GW resources and their flows. Users may have the wrong impression of water availability through considering GW stress map displaying estimates of the mean annual recharge, and hence a bad representation of the consequences of GW extractions	nice to have	1	Associated with the solution of setting a percentage use of GW compared to SW, an additional parameter would be "the proportion of the recharge from rainfalls used". In the results, an indicator showing the GW use provided by that discharge from rainfalls could be provided to make the impacts associated with GW uses visible at a simplistic level and make sure to explicitly mention that the displayed results aims at acknowledging GW uses in the model but are not providing realistic values.
41	Unclear whether users would understand the parameters under the scenario editor	Some of the terms used or annotations could be difficult to understand for non-expert users in specific disciplinary fields. For example the agronomic parameter Ky is not universally understood by all users and require to be clearly defined	must do	1	Provide a support package with the definition of the parameters and information to how parameterising them

42	Unclear whether the results provide a good representation of the impacts in a basin	The indicators provided in the result section could fail to provide a realistic vision of the impacts in a basin, as some water systems and processes could be missed by the model		1	Identify means to produce outputs that are going to be useful in terms of indices rather than providing indicators themselves. One way is to ensure that the calibration data values are within a plausible range (cross-check indicators)
		The lack of consideration of GW extractions in the model could be a big limitation especially in basins highly dependent on GW resources, especially when teaching water resources management	must do	2	Include GW resources and uses and well maps to have a better representation of GW resources impact by different water uses in arid basin especially. A simple approach would be to consider a simple storage capacity of the aquifer and the wells for the outflows from the aquifers and add a simple balance equation.
			must do	3	Under irrigation (and demands) enable users to split water uses between SW and GW (as a proportion of uses) and then report in the results the level of GW uses based on the percentages provided, to acknowledge the use of GW at a simple level. The percentages could also be set as monthly values, pattern rules or timeseries.

			nice to have	4	In addition to specifying the proportion of GW extracted in a BF, enabling user to set "the percentage of the recharge from the rainfalls used" or computed from the WHYMAP dataset could be provided and an indicator displaying the proportion of the recharge from rainfalls used, in the results, could help acknowledging in a simplistic manner GW uses and potential impacts from extractions
				5	Enable users to specify, at a basic level, a GW mean annual volume
		The lack of consideration of man-made drainage systems in the model could be a big limitation especially in basins highly dependent on drainage systems, especially when teaching water resources management	must do	6	Include man-made drainage systems in the tool in addition to SW systems through including surface water canals map and allow users to potentially set rules to use water from the canals

		Users may want to have a broader range of indicators to compare in the results to have a more holistic idea of the impacts on water resources in a basin	nice to have	7	Include the Basinpedia indicators in the results and enable users to compare them to see how they change compared to the current situation. In addition, index reflecting the time water is reused in a basin, linked with some Water National Account datasets, could be used too (e.g., management purposes or to have a better idea of water availabilities)
			nice to have	8	Include additional indicators reflecting the impacts of water uses on social, economic and ecological factors
			nice to have	9	Provide users with the seasonal variation of an indicators such as the BWS index as well as which user (i.e., D&I, agricultural) would be the major user through time. It would provide users with an idea of the seasonality of impacts and also be used as an equity indicator.
		Some users may think that the ecological component is not properly developed in the tool and	must do	10	Provide users with an idea of how changes in water in the basin could influence the "species" indicator in the results

		may want to see more of its representation			
				11	Clarify the limitations of the software for users to consider looking at other information to have a proper idea of ecological impacts. For example, under flow metrics, add a sentence about the limitations of the indicator such as" this is how the flow regimes are predicted to look towards. You need to look at the ecological impact further from that"
43	Unclear whether would be aware of the minimum tasks to realise to create and edit a model/scenario as well as evaluate at which stage they are in the process	Some users may need to be guided step-by-step during the model/scenario design and, if leaving a task, be able to know where they were in the process and what steps need to be edited	must do	1	Change the tabs colour when going through the steps and keep the last tab edited in the tool in colour for users to remember where they were in the edition process.
				2	Provide users with dialogue boxes to guide them and display the workflow in the UI

44	Unclear whether the model enable users' visualisation and interactive setting of features of interest in a basin	Some users may want to know where in a basin are located major features such as industries, dam, arable soils, for instance, or set on the basin model map these features	must do	1	Allow the user to interact with the map to set features of interest.
45	Unclear whether users could set irrigation types	Some users may not be aware of how BF represents irrigation types and the assumptions made with the supply efficiency parameter	must do	1	Enable users to specify the type of irrigation technology
46	Unclear whether the environment would receive the necessary amount of water to support its physiological and biological processes when setting environmental flow releases from a dam	Some users may wonder if water would be effectively delivered to the environment in its whole or if it could be intercepted and reduced by other users	nice to have	1	Enable users to decide where to allocate water in a basin to ensure the proper visualisation of the impact of different water allocation effects
47	Unclear whether users could prioritise water allocations in a basin	Some users may want to decide how to prioritise water uses in a basin to evaluate different management scenarios under or not climate changes	nice to have	1	Enable users, especially water professionals, to set priorities for water resources allocation in a basin to evaluate different management scenarios
			nice to have	2	Implement an add-on feature or analysis with some kind of optimisation tool to allocate water between different users

48	Unclear whether the list of crops is ordered alphabetically	Some users may consider that the crops in the list are ordered alphabetically and further check if a crop of interest may be in the list	nice to have	1	Order the different crops in alphabetical order
49	Unclear whether the climate datasets for a scenario could be changed afterward	Some users may want to change the climate datasets for a scenario and may like to be able to change of climate datasets after creating a basin model and getting in the editor page	nice to have	1	Enable users to go backward to change of climate after editing a scenario
50	Unclear whether users would be aware that some functionalities display may be delayed due to network issues or the time for the tool to process the information or errors associated with the choice and/or edition of models	Some users may believe that the tool could not show some features that may interest them, such as the administrative areas on the map.	nice to have	1	Provide users with an alert or error message in the time to progress the information or the network quality could reduce the speed to display features of interest
		Some users may not be aware of potential issues with their online connection	nice to have	2	Provide some kind of feedback to the user (and not time) telling him/her he should wait as the process would be soon achieved or do something else as it would take longer
			nice to have	3	Identify a way to speed the system processing time

			nice to have	4	Enable users to let the software test their connection and inform them of potential issues with the network
		Some users may feel annoyed by the time to progress information	nice to have	5	To reduce the time of processing, guide users with telling them what parameters are paramount to edit and not
			must have	6	Provide a message to users with specifying if the time of processing the information is due to an error, problem with the network or the chosen level of resolution and number of reaches
51	Unclear whether the map could be enlarged to ease observation	Some users may want to interact with the map and enlarge it to ease their interaction	nice to have	1	Enable the map in the Basinpedia and the scenario editor to be enlarged to ease visualisation
			nice to have	2	Explain, in the quick start guide how to deal with the map (as well as other features such as the global water consumption per capita scale under 'demands') and screen size issue to ease the use of the tool
52	Unclear whether users could access the information in the Basinpedia after creating a basin model	Some users may like to be able to access the information in the Basinpedia after creating at basin model	nice to have	1	Enable users to access the Basinpedia information.

53	Unclear whether dams location and not only their artificial lakes could be visible on the maps	Some users may want to locate the dams on the map used to create reaches to set points with known gauges at the dam locations	nice to have	1	Facilitate users identification of known gauge stations next to dams when designing reaches
54	Unclear whether land use changes and timing could be visible in the land uses tab	Users may want, not only to have the proportion and coverage of the different land uses, but also an idea of land use changes in time. For example, agriculture lands could be under fallow during cropping inter-season or during summertime, the grasslands are bare lands and no longer grasslands	nice to have	1	Provide information for the time and date associated with the displayed land uses, and information about known land use changes in time
55	Unclear whether users could report issues and have access to a reporting function at any place in the interface	Some users may be facing issues at different locations in the interface, including pop up windows, and may not be able to report issues from their page as the 'provide feedback' button is not directly accessible everywhere	nice to have	1	Ensure that users could report issues in any page and windows in the interface

56	Unclear whether users would notice, from the summary table under the scenario editor, that, when selecting inconsistent climate datasets, the tool would not process and calibrate the climate for a scenario	The summary table under the scenario editor provides indications about the status of the RR calibration, a red cross implying that the calibration could not be progressed further. However, users may not be aware of the meaning or the presence of this symbol in the table.	nice to have	1	Ensure that the error for progressing the RR calibration is more prominent and visible to the user
57	Unclear whether users would understand how to delete a scenario	The process to delete a scenario could be misleading for some users as they have to delete the scenario when selecting their basin model first and eliminating the scenario under 'models'	must do	1	Enable users to delete a scenario under 'scenarios'
58	Unclear whether issues could be corrected rapidly as the number of users grow	With increasing number of users, the number of potential issues reported would increase	must do	1	Set a maintenance team to deal with the issues faced by the users

59	Unclear whether 'borders' under the Basinpedia implies that international basins only are considered in the tool	In some countries like Australia, 'borders' as international borders for a basin could make no sense to some users	nice to have	1	Consider a second level of divisions such as states or other lower levels to reduce the potential for users' misunderstandings and provide more factual information regarding the administrative areas encompassing a basin in countries without direct international borders. Another level, especially relevant for Australia, is the consideration of water management areas such as NRM borders.
60	Unclear whether users would expect to see other indicators for 'species' under Basinpedia	Some users may expect to see other species or biodiversity indicators under 'species' and not only fishes.	nice to have	1	Provide additional species indicators, in particular GW dependent ecosystems specie indicator
		Some fish species may not be registered in the IUCN dataset, wrongly indicating to users that fish species are not present in a basin	nice to have	2	Include additional fish species dataset in the tool to complete the information provide about fished under Basinpedia. A dataset could be, for Australia, the "Atlas of Living Australia"
61	Unclear whether users would be aware of the future developments for the tool	Some users may disregard the tool and/or reduce their engagement with it due to the absence of knowledge regarding potential future developments for the tool	nice to have	1	Clarify what additional features and data could be available when global datasets could be released in the future to add value to the tool.

			nice to have	2	Provide users with a version of BF using models with more complex data
			nice to have	3	Clarify what additional plug-ins could be included in BF in the future and their conditions of inclusion. For example, GW model such as MODFLOW plug-in
62	Unclear whether the banner under 'crops' saying "no irrigation area" implies that users could interact with the map to set irrigation areas	Some users may think that they could interact with the map and set boundaries for the irrigated area in their reaches			
63	Unclear whether the default values are set within a plausible range of values	Less experienced users may think that the tool provides them with plausible default value, that they could use directly.	nice to have	1	Provide users with more plausible default values to ease their experience and understand the impact of their choices in their basin of interest
			nice to have	2	Provide indicative ranges of plausible values with the default ones to have an idea of how these default values could vary
		Some users may not pay enough attention to the default values leading to unrealistic results			

64	Unclear whether users could explore industrial developments scenarios	Users may want to be able to explore different type of industrial developments in time	nice to have	1	Include global industrial datasets for industrial water uses with a finer visualisation of the different main industrial sectors found worldwide (i.e., hydropower, thermal energy and manufacturing) and their respective proportions of industrial water uses
65	Unclear whether users could do other tasks while waiting for the software to process the calibration of already edited parameters	Some users may want to continue editing parameters while the model calibrates already entered data but, in some cases, may risk having to redo the calibration again if quitting an interface to edit another parameter		1	Implement some kind of caching to ensure that users could realise other tasks while the tool processes information. They could allow the users to decide if they want to wait for the process to end or not and launch the process by asking the user to click on a command button saying "calculate everything for me" for example
				2	Provide users with some indication or warning message that quitting the page may cancel the calibration process

66	Unclear whether users could visualise the map with the location of the gauge stations while using the calibration wizard	Some users may want to check the estimated annual or monthly mean runoff values in the wizard and locate the reaches with the corresponding on the map, without, when changing of window, cancelling the calibration process		1	Enable users to access the map in the calibration user when setting mean annual or monthly runoff target values
67	Unclear whether users could set their own values for the annual and monthly runoff under the calibration wizard and the calibration editor	Some users may want to try to set their own target values and could be prevent of doing so in the tool		1	Enable users to edit their own target values for the RR calibration using either the calibration wizard or the scenario editor interface
68	Unclear whether users would make sense of the different icons and symbols in the tool	Some icons may not make sense such as the balance symbol for the RR calibration	must do	1	Display information about the icon when scrolling the mouse above it
69	Unclear whether the users would realise that the spatial granularity of the tool is not fitted for too small catchments	Some users may want to divide their basin into very small reaches to have a more finer and local approach, and may not be aware of the time and difficulty to set scenarios with too many reaches		1	In the documentation, especially in training materials, provide a kind of disclaim to clarify to users that using too many reaches is not adviced due to the time and complexity to set the scenarios thereafter and analyse and compare the results

			nice to have	2	In addition to providing a disclaimer in the documentations, provide a warning message in the tool to advice users that setting too may reaches may not be an appropriate idea. Example of messages could be "you are trying to create too many reaches" or "are you sure you want to create that many reaches, remember BF is an entry level tool" or some message of the like
70	Unclear whether users could not be confused by the lack of consistency of the units used in the interface as well as with the dowload excel files	Some users could be confused by the change in units.		1	Ensure that there is consistency in the units used for parameters in the tool and downloadable files
71	Unclear whether the OFS function level of details is not compromising the tool	Some users may be confused by the inconsistency between having a global dataset with a coarse approach and local parameters requiring more specific data and a finer level of details. This inconsistency could lead users to misinterprete the purpose and fitness of BF	nice to have	1	Simplify the OFS approach with having less specific operating rules parameters and more a buffer function allowing users to use the amount of water available in a river at a particular time plus whatever amount of water presents in a storage that hasn't been used yet. And when there are surplus of water, the storage get refilled.

72	Unclear whether the storage reliability threshold value of 85% could be changed	Some users may want to use different thereshold values based on water uses and country set thresholds for gauge stations		1	Allow users to set other threshold values. 85% could be kept as a default.
73	Unclear whether users would understand the assumptions associated with the default values and how to interprete the results	More inexperienced users would tend to use the default values but may not understand the assumptions made in the model to set such values and how to interprete the results consequently	nice to have	1	Provide users with an explicit documentation and explanations regarding the default values
		Some users may not understand the assumptions around the default values and would need additional explanations to understand how they were set and if the assumptions fitted with the purpose of their case study and/or needs to be changed or not.			
74	Unclear whether the time for processing the information in the tool could make it purposeful for use in teaching labs	The time associated with progressing the information could be too long making teaching labs challenging.	nice to have	1	Make available pre-calibrated models for teaching uses to reduce difficulties associated with the time to calibrate scenarios
75	Unclear whether users could generate missing data	Under 'run scenarios' the model provide a function under 'data errors' to generate missing data. However, the function appears not to work and prevent users to run a scenario			

76	Unclear whether users could apply the calibration of parameters for a reach to all the other ones	Some users may want to set identical input data to all reaches and may want to avoid editing them to each reach one by one	nice to have	1	Enable users to "apply to all reaches" edited parameters for different components of the scenario editor
77	Unclear whether users would know how to deal with RR calibration issues	Some users may find issues to calibrate the RR and may need guidelines to resolve their issue and calibrate their scenario	nice to have	1	Provide users with a documentation with guidelines and tips about how to deal with some problems met when calibrating the RR model
78	Unclear whether land availability and changes could be visible in the tool	Some users, especially with a more local focus, may want to identify where the different land uses could be presented in the map	nice to have	1	In a statement, clarify how land uses and changes in time are delt with in BF and if users could or not choose different part of the basin for cropping
			nice to have	2	Show on the map land availabilities to enable users to understand where the different land uses are located and what is the land available for agriculture
		Some users may want to do irrigation expansions scenarios and may not be aware of some limitations for their crops when considering marginally and moderately suitable soils that could reduce the potential for irrigation developments	nice to have	3	Provide users with a disclaimer regarding the land suitability function to aware them that the scenario they are editing is not realistic, considering the type of crops selected

79	Unclear whether GW recharge values in the water balance results are realistic	Some users may not notice inconsistencies in the results such as irrigation use lower than GW recharge from irrigation.	must have	1	Correct errors and inconsistencies in the interface associated with GW recharge values
80	Unclear whether the index of alteration under 'flow metrics' could provide indications of temporal changes	Some users may want to know if certain periods or certain years could not achieve certain metrics	nice to have	1	Displays temporal changes with the flow metrics on a monthly basis and inter-annually
81	Unclear whether users understand the relationships between the different parameters in the crop model	Some users may want to understand how these parameters interact and influence each other in the crop model	nice to have	1	Make explicit the relationships between the different parameters
82	Unclear whether users could compare the fitness of the different rainfall data sets in a selected basin	Some users may have issues to be able to compare different rainfall datasets, potentially as a result of the absence of gauge stations associated with a dataset in a region, which could limit the interest in the function and the selection of more suitable datasets for their case study			
83	Unclear whether users would identify all the functions of BF. Case of the population estimate function.	Some users may not be aware of some functionalities in the tool such as the population estimates (current and future)	nice to have	1	Case study documentation to help users identify the different potentiality of the tool

84	Unclear whether the climate function could represent changes in temperature	Some users may want to have access to changes in temperature through time to have a better insight of the potential influence of temperature on land and water systems	nice to have	1	Include temperature datasets for historic and future climates to provide users with more factors associated with the climate change
85	Unclear whether the colours for the GW indicator in the Basinpedia could not be confusing	Some users may not understand the selection of brown for 'low to very low' and blue ranges for the other indicator levels		1	Make sure that the choice of colours is consistent to avoid users' confusion when interacting with the GW indicator in the Basinpedia
86	Unclear whether users could compare more than two scenarios together	Some users may want to have an overview of all the possible results for different scenarios	nice to have	1	Enable users to compare more than two scenarios under scenario comparison and allow them to access more visualisation tools such as bar graphs instead of just tables. Also provide temporal information for example how changes in water could impact fishes on a monthly basis and interannually
87	Unclear whether different changes will impact different socio-ecological systems over time	Some users may want to visually be able to see, both when comparing scenarios and at a single scenario level, how changes on a monthly basis and inter-annually could impact different uses and users in a basin	nice to have	1	Enable users to have an idea of when in a year and between years some changes may impact different water users

88	Unclear whether the colours chosen in the scenario comparison table for the water balance could not influence users interpretation	Some users may think that a reduction of 65% of water uses in agriculture could be bad, as displayed in red, whereas it could also be interpreted as a good outcome if the water productivity is higher (i.e., more production with less water uses)			
89	Unclear whether some users could visualise colours	Some users could be colour-blinded and the use of colours to inform a basin outcomes may not be insightful for them			
90	Unclear whether the range of colour with the map displaying the population density is informative	Some users may understand that different colours are indicative of different population densities but would also have a numerical idea of the range of population densities		1	Provide a bar scale with indications of the density of people, as a range for instance
91	Unclear whether users could download the scenario comparison tables	Some users may want to be able to download the information from the scenario comparison as well as have information regarding how the different scenarios compare to each others		1	Enable users to compare more than two scenarios and download the results of the scenario comparison

92	Unclear whether users would not confused 'demands' and the percentage of water returned to the system to all sectors i.e. agriculture and D&I	Some users may understand 'demands' broadly with including agriculture demands and may think that the % water return is associated with all demands			
93	Unclear how users could interprete the %water return under 'demands'	Some users may interprete as beneficial for the environment as more water could be returned to SW or as a display of better conservation practices or reuse of water			
94	Unclear whether the jargon used is intepreted by all users similarly	Some users may misunderstand what is defined as 'supply efficiency' according to their background		1	Clarify what is defined by supply efficiency in BF to avoid misunderstanding about the parameter and limit edition errors
95	Unclear whether users could remember the rational for their choice and conclusions	Users may need to keep track of their workflow, assumptions, results and questions to explore. It would benefit tem personaly but also provide transparency about their workflow for external persons to analyse their work and /or help them to solve issues or misunderstandings		1	Encourage users to provide a description of their workflow and assumptions. This notes could be downloaded with the model results to ease analysis. It could be done on a similar basis as for ODD protocols
96	Unclear whether the level of data included with the model download is reflective of the tool	Some users may want to download the model and have access to all the information included in it	must do	1	Ensure that the level of data of dowloadable results and the model is included

97	Unclear whether users could set water transfers	Some users may have issues to set existing water transfers	nice to have	1	Include global datasets directly providing users with existing water transfer data to ease calibration
		Some users may not understand how to use the function			

E. Deductive thematic analysis with emerging themes for the questionnaire

Issues identified in Table D1 and Table D2 were aggregated and organised, based on the formulation of issues and solutions, according to for uncertainty communication types (Chung & Wark (2016)[6]), as summarised in Table E. Numerical values represent the number of issues belonging to different uncertainty communication types; the total number equally 254 issues.

Table E. Overview of associated themes for the questions based on the categorisation of issues according to uncertainty communication types.

Uncertainty Communication types	**Type of themes for the questions**	**Number of cases**
Accuracy	Associated with the Basinpedia search function to locate a basin	1
	Associated with the names provided for different reaches or districts	2
	With the ability to discriminate different features on a map	2
	With the ability to predict future changes because of natural and/or anthropogenic changes	2
	With the ability to represent practices in a basin and land uses	2
	With the ability to set values when using predefined setting ranges	1
	Ability to position reach nodes at desired locations	1
Completeness	With usability and tasks' realisation guidance (including adding details to identify breaking points for reaches creation)	17
	With the clarity of the information provided in terms of words, colours, definitions (including the specification of the type of events considered), spatial and temporal coverages, default values, symbols, units, titles, validation of performance for RR calibration process	35
	With data meaning and coverage (including default values and climate change datasets)	14
	With the origin, assumptions and/or means of calculation of the qualitative and quantitative data parameters provided (including dam operation rules)	15

[6] Chung, J., & Wark, S. (2016). *Visualising uncertainty for decision support*. Defence Science and Technology Group Fishermans Bend Victoria Australia.

	With rules of thumbs and realistic assumptions for the user to consider factors and their associated effects not modelled by the tool	3
	With the structure and relationships of the different build-in models and/or relationships between a model parameter	5
	With the representation and/or evaluation of different water management options	5
	With the purpose and targeted audience for the tool	2
	With the ability to cross-validate information	1
	With the purposefulness and comprehensiveness of figures and tables	1
	The accessibility of cited references and associated sources or functions	2
	The ability to represent and acknowledge different types of uncertainties and communicate them	1
	The fitness of model calibrations	1
	With the clarity of future scope and implementations for the tool	1
Currency	Associated with the difference between the input data provided or default value provided with observed values over time	1
	Associated with the lack of reference regarding a dataset time coverage	5
	Associated with the visibility of data time coverage	4
	With the time to process calibration tasks, identify a basin (based on the level of resolution) and/or compute results	2
	With the ability to timely saved configurations	1
	With the notification of processing time and/or issues	1
	The compatibility of the processing time with activities timeframe (e.g., lab teaching)	1
	With the evolution and fluctuations of some indicators over time (e.g. IHA)	1
Credibility	Associated with the absence of completed references regarding datasets and models	11
	Associated with differences between different datasets and/or models dealing with similar functionalities and/or purposes	1

	Associated with the purposefulness and insightfulness of an indicator/dataset/model	1
	With the sampling methodology to estimate values	1
	With the predictive ability of the model in the absence of gauge stations or when considering climate change datasets	1
	With the ability of the model to ensure the adequate selection of a basin in the absence of cross-validating methods	1
	With informing users about the potential or not to import their own datasets to the tool	1
	With the governance strategy to consider and correct issues identified in the UI	1
	With the rational and validity of default values	1
Interrelatedness	With the possibility to access information presented in different parts of the UI regardless of its workflow	1
	With the potential to use the different indicators used for contextual purposes as outcomes reflective of a basin system response to changes	2
	With the connection between different indicators, parameters and components in the UI (including calibration progress and scenario run)	11
	With the association of the parameters with different policy actions	1
	With the location of different described features and associated availabilities (e.g. Land suitability)	2
	With the type of information required to set a parameter	1
	With the representation of time/seasonal/spatial fluctuations	3
	With the representation of all water users and water uses	3
	With the representation of different policy options	1
	With the representation of different scenario results (e.g., how are future changes represented? Are mean values sufficient?) [including comparison between scenarios]	4
	With the connection between water quality and water scarcity	1
	With the representation of SW and GW connectivity	1

	With the representation of changes in the water supply (for water transfers)	1
	With the representation of drainage systems in irrigation and their operation (especially in developing and arid countries)	1
	With the representation of future socio-economic developments scenarios and their impacts on water resources	1
	With the representation of physical parameters in the model and suggestion of potential impacts on water resources and associated uses and users	1
	With the relationships between colours and numerical values (missing legends and scales)	1
Consistency	With the ability of zoom and search functions to display associated places and/or artifacts	2
	With the logic and clarity of the symbol or colours used and their associated components	2
	With the terminology used to describe or define a parameter	2
	With the ability to reports findings or update scenarios everywhere in the UI	1
	The correspondence between values and units or names and codes (within the UI or with downloadable files)	4
	The correspondence between the model structure and the water balance results	1
	The correspondence between figures information and their associated legend (including axis legend and scale between different scenarios)	2
	With the redundancy of/duplicated information	1
	With the correspondence between the intent level of complexity of the model and the level of complexity suggested by the parameters for the different built-in models	2
	With the validity of the results calculated by a model (cross-validation means to evaluate if the results are within the model range of applicability)	1
	With the purposefulness of a parameter to describe adequately potential impacts on the supply (for example, GW real recharge from rainfall infiltration)	1

	With the setting of parameter values and the amount of water allocated to different users	1
	With the order of parameters or their organisation in the UI	1
	With the similarities and differences in characteristics between the model downloaded and the UI	1
Precision	With the adequacy of the model to predict results when considering parameters' values outside its analytical range or missing data	4
	With the simplification made and impact on the representation of water withdrawals	1
	With the confidence level of the results	1
	With the performance of the model to calibrate climate datasets and predict hydrological changes	1
	With the ability of the model to provided adequate measurements	2
	With the representation of the influence of different factors on the results (sensitivity)	1
	With the ability of the model to guide users when selecting climate datasets (e.g., climate dataset comparator)	1
Experimental	With the ability of users to change default or computed (for RR) values to explore customised scenarios	3
	With the ability of users to be aware of the dispersion of the results and of potential impacts associated with natural and physical variabilities	1
	The easiness to use the zoom function and visualise features of interest	1
	The ability to close or access the full information using pop-up windows	1
	The ability to consider different management policy (demand/supply such as water allocations)	2
	The potential for interactive map to set and/or customise features of interest	1
	The potential to explore different water demand management options	1
	The potential to customise threshold values for some indicators to reflect existing management rules	1

Lineage	With the clarity regarding the process to visualise a features or results of interest or delete a scenario	3
	With the computation of missing data values	1
	To ensure that input data have been properly saved for distinct scenarions	1
	With the logic of the results displayed and representation of different parameters in a model	2
	With the ability to access different data details (e.g. Downloadable data) or datasets (go backward)	4
	With the ability of the model to signal inconsistent choices	1
	With indications of the workflow state and tasks to be done	1
	The ability to notify issues anywhere in the UI	1
	The ability to do tasks while the tool still processing configurations	2
	The ability to generalise configurations rather than going through each individual reach	1
	The ability for users to keep track of observation and findings	1
Subjectivity	With the information displayed and understanding of the task to achieve	2
	With the information displayed and understanding of the results (e.g. Colours used)	2
	With the content to be found because of the ambiguity and broadness of the wording used	1
	With the potential interpretations and implications of the configuration of some parameters or representation of features in a system	2
Total issues		254

F. Evaluation of Basin Futures using the CAA questionnaire

The questionnaire was used to re-evaluate Basin Futures, more than a year following its first evaluation of uncertainty communication using the heuristic approach. The results in Table F show partially- and non-treated issues, previously identified from the two evaluations of Basin Futures, as well as new issues. The total number of partially and non-treated issues was 156 issues compared to 254 issues initially.

Table F. Results from re-evaluating Basin Futures using the CAA questionnaire.

Blank cells for are related to the absence of additional information due to new issue (treatment state) or absence of identification of issues by the evaluators involved in initial evaluations of Basin Futures (two last columns with mention of the label for initially identified issues)

Link to the questionnaire	Issue label	Issue type	Issue description	Treatment state	Description	Related to the heuristic approach (issue label)	Related to the expert issues (issue label)
Q1-Scope	1	Uncertainty	Lack of clarity regarding what is included under assessing water resources. Different factors could be assessed related to water resources such as water quality, water availability, surface water resources, groundwater resources	Partial	The **must do** solution for issue 13 from the **expert review** was considered to provide, in the Basinpedia, some indications of water quality issues in a basin using a set of indicators as suggested. The nature of water resources that could be assessed remains unclear.		12,13,30

Q1-Scope	2	Uncertainty	Lack of clarity regarding the targeted audience. It is assumed that decision makers are targeted and therefore planners and policy makers	Partial	The home page mentions 'decision-making', which is still ambiguous. The '**must do**' suggestion from the **expert review** to clarify the targeted audience has been considered but still remain ambiguous. Providing an illustration of solution may be needed to ensure changes will be acceptable.		1
Q3 - workflow	3	Uncertainty	There is no clear link to the home page from the UI. The user needs to click on the "CSIRO" logo to get redirected to the home page.	New			
Q3 - workflow	4	Uncertainty	The 'documentation' redirects the user to the bottom of the page, and the information at the bottom is also redirecting the user to another page. This could be perceived as redundant and could be simplified.	New			
Q4-transparency	5	Missing information	It is unclear due to the colour of the police how the user could access the documentation	New			

Q3 - learnability	6	Missing information	It is unclear for a user to directly understand the steps to create a model, then scenarios and run them from the home page or after signing in. The menu is not sufficiently explicit by itself to understand how to use the tool.	New			
Q3 - learnability	7	Missing information	It is unclear how to get started from the home page or how to get back to a working task.	New			
Q3 - workflow	8	Missing information	It is unclear what the purpose of the Basinpedia is, even from the walkthrough. There is a need to clarify what the Basinpedia aim at, what it could not do, and potentially how some users may have extended its use.	New			
Q3-learnability	9	Missing information	It is unclear whether the user will easily identify using the provided indication below "Basin details" or page 2 of the walkthrough. The mention of "clicking" alone could be confusing. In addition, the scale of resolution and consideration in some cases of reaches instead of the basin itself may need additional explanations.	New			

Q4- clarity	10	Uncertainty	The position of the dialogue box makes it difficult for a user to identify the mentioned tab.	New			
Q4 - transparency	11	Missing information	All the main tabs in the walkthrough are explained except for 'Land cover'.	New			
Q3 - learnability	12	Missing information	It is unclear whether a user will be able to find a basin of interest based on the average size of a basin. For example, in the case of the Brahamani basin, the basin area is of 39,033 km^2. If selecting a level 5, that should include the basin, the limits of the basin are not representative of the basin itself but the Baitarani and Brahmani basins.	Partial	To some extent, the issue identified by the **review** was considered as the average size of a catchment is clearly specified to select a level of resolution to identify a basin. Two categories of solutions categorised as **'nice to have'** (clarify by writing) and **'must do'** (guide through a support package) have been implemented. As for the **heuristic evaluation**, suggestion of guidance has been considered, also as a 'must do' and 'easy' to implement, as well as to improve the visualisation of process of a basin boundary when changing the level of resolution.	1,2	5

					However, none of the suggestions provided were considered. Rather the 'must do' solution from the review was considered instead.		
Q4 - clarity	13	Uncertainty	The information and associated name are at the reach level and not the basin one. The contextual data could be interpreted for the whole basin and not understood to be for each of its constitutive reach.	Not treated	The review considered that issue as a 'must do', which was not taken into consideration. As for the heuristic approach, it was graded as 'worthwhile'	3	7
Q5-data customisation	14	Missing information	Some of the metadata, as for the land cover one, do not provide enough information to be understood. Contextual by itself is not clear when considering how the information could be used. There is a need for additional information for the user to understand how this information could be used.	Partial	A big effort of transparency of the sources for the datasets, for the Basinpedia, has been realised. However, remains to be improved. Aspects related to the use of the datasets is too vague and not backed by links to relevant documentations and case studies. Priority levels do not appear influential as experts consider the addition of sources as 'nice to have', potential as	11,19,21,23-28,33-35, 92, 99, 107, 112, 113	10,21,29,33, 59

					information in the Basinpedia is not used further in the tool. As for the novice, according to the solution provided, levels are either 'worthwhile' or 'must do'. It is possible that the demonstration of purposefulness about what could be done with the datatsets to analyse a case study may have been influential, but the release of the Basinpedia seems to be the main reason.		
Q3- workflow	15	Missing information	Some users coming back to the tool may need guidance to get back to their model and scenario of interest. It is unclear whether the pathway to open first a model and then a scenario is intuitive enough from the current state of the UI.	Not treated	Not treated, despite the expert's categorisation as a 'must do'.		43
Q4-clarity	16	Usability	Uneasy to read the full content of the metadata, especially if using a computer with a small screen. Users may not know how to read the full information using the	Not treated	**Not treated,** whatever the level of expertise and priority level		11

			zoom out function. In addition, if containing a lot of text, zooming out could make reading a difficult task due to the size of the text.				
Q4 - clarity	17	Usability	Uneasy to close a window. The user may be unaware to zoom out to access the close window icon.	Not treated	**Not treated,** whatever the level of expertise and priority level		11
Q5-practice	18	Usability	Some definitions may be too jargonish for a user to comprehend. There is a need to simplify definitions according to the targeted audience, with also considering different levels of expertise if appropriate.	Not treated		16,52,53,54, 57,76,77	92,93,94
Q4-clarity	19	Missing information	If willing to have access to the contextual information about one of the reaches, it is unclear whether a user will find how to go back to the visualisation of the full basin	Not treated			52
Q4-clarity	20	Risk of error	The name of the districts may be erronated in some cases	Not treated		3	

Q4-clarity	21	Risk of error	Some protected areas appear outside of a basin in some cases. It is however possible that part of the protected area lies within a basin. There is a need to either remove protected areas strictly outside of a basin or to extend the diameter of the circle representing a protected area to show it overlaps a basin.	Not treated		14	
Q4-clarity	22	Risk of error	Even though specified in the metadata, a user could misunderstand the information provided in the table for being at the reach level rather than country level	Not treated		18	
Q4-clarity	23	Risk of error	For species, there is an apparent issue when selecting "all", as none of the species in a reach appear, whereas they appear while deselecting "all"	New			
Q4-clarity	24	Usability	Some pop-up windows, including the ones for the model creation, have a too transparent background, making reading uneasy.	New			
Q3-clarity	25	Uncertainty	When considering the index of hydrological alteration under	New			

			scenario results, it is unclear whether the percentages reveal high, moderate, or low levels of alteration. The choice of colours is not reflective of the level of impact on flow regimes				
Q3- data parameterization	26	Risk of error	Incompatible datasets could be selected without interrupting the program. One potential issue with using incompatible datasets would be the lack of ability to consider long-term scenarios, if considering a climate change dataset with an historical dataset.	Not treated			19,22,77
Q3-data parameterization	27	Risk of error	Some users may mistake rainfall stations from gauging stations and get confused by the absence of location of stations.	New			
Q4- transparency	28	Missing information	No information is provided related to the Global Historical Climate Network.	New			
Q3- workflow	29	Missing information	There is no clear purpose for the edit button if using the scenario editor. However, the edit button appears relevant when wanting to get back to the scenario editor after running scenarios. There is a	New			

			need to clarify the purpose of the 'edit' button.				
Q3-workflow	30	Usability	There is no possibility to change the climate scenarios after their configuration. A user may need guidance in how to change climate datasets.	Not treated			49
Q3-learnability	31	Missing information	A user may struggle initially in how to use the scenario editor, and may wonder if there is any priority order when parameterising a scenario	Partial	To some extent, some adding in terms of definitions and sentence to explain the purpose of different models and parameters have been considered. Suggestion of the **review** to consider a walkthrough for RR parameterisation for example, or to clarify the definition of different parameters have been taken into account. As for the existence of specific order or workflow , it is still to be addressed.		20
Q3 - workflow	32	Missing information	The purpose of the table is unclear and may need to be clarified	Not treated		38	56,68,78

Q3 - learnability	33	Missing information	No information is provided in how to proceed to set the rainfall runoff. There is also no clear differences between the manual and automatic calibration using the wizard.	Not treated		41,46	67
Q4 - transparency	34	Missing information	No information about the built-in model for rainfall runoff and meaning of the parameters provided.	Not treated		42	18
Q3- process progression	35	Usability	The last message in the calibration wizard may be unclear as how to proceed. There is no indication that the user needs to open the data processing tab to initiate the process and then there is a lack of clarity related to the file to open under results. Similar headings should be kept for consistency	Partial	The path to apply calibration is described but still presents some ambiguities to be corrected	38,45,94	20,34,76
Q3-learnability	36	Risk of error	Completing the calibration wizard, it is unclear whether users	New			

			may not select the "apply computed parameters" instead.				
Q3- task progression	37	Missing information	There is a need to clarify that the user needs to click on "running" to start the calibration process.	New			
Q4-clarity	38	Usability	The number of calibration results could become important at one stage and there is a need to manage unused data.	Not treated	Not treated - Potential add a data management category		57
Q4-transparency	39	Missing information	If considering a specific method of calibration, the results provided are related to the built-in model parameters. It could be confusing, especially for novice modelers due to the lack of information related to the model.	New			
Q3 - learnability	40	Missing information	There is no guidance related to how to return to the scenario editor following the application of the rainfall runoff calibration.	New			
Q3 - learnability	41	Missing information	Guidance is needed in how to configure storages and related to the purpose of the different thumbnails	New			
Q4-clarity	42	Usability		New			

			The zoom function allows for the location of pre-identified storages, but it is still difficult to visualise the location on the map, as too tiny				
Q3 -learnability	43	Missing information	To configure hydropower, it is unclear whether a user would be aware of the ability to configure hydropower when using an available storage and to go to the "configured storage" thumbnail for that matter	New			
Q5-customisation	44	Usability	There is no possibility to consider more than one storage using the tool or to combine available and configured storages. In some cases, a user may need to consider more than one storage in a reach.	Not treated		51	
Q4-transparency	45	Missing information	The purpose of the estimated storage properties is unclear.	New			
Q4-clarity	46	Usability	The size of the window is too tiny to visualise or check numerical values	New			
Q3 - learnability	47	Missing information	It is unclear whether a user would know how to parameterise the crops setting and what the	Not treated		61	20

			purpose of the different parameters are.				
Q4-transparency	48	Missing information	It is unclear whether users will understand what is aimed by supply efficiency under agriculture and on what the percentage values are based on.	Not treated		93	45
Q4-transparency	49	Missing information	How to identify the soil texture could be a complex exercise, especially as most geological data do not include systematically soil texture data.	Not treated			16,17
Q3 - task workflow	50	Missing information	When using the crop estimates model, there is no information relative to the types and nature of the crops considered and associated planting area, as well as no clear information about what other parameters need to be set in the crops table following the application of the estimates.	Not treated		68,69,70	
Q3-learnability	51	Usability	Some users may be interested in using crop estimates other than irrigated.	New			
Q3 - workflow	52	Risk of error	There is no evidence of default data used by the tool, which could lead to some errors when analysing the results	Not treated		44	16,20, 25,35,63,73

Q4-transparency	53	Missing information	It is unclear from the description of the model what the minimal size of a storage used for irrigation purposes will be, that could be used by users to set up the model. Also it is unclear whether a priority order is considered related to how the water is pumped, as well as the water sources that is conisdered in the model (surface water and/or groundwater).	Not treated		73,78,82	18
Q3 - learning	54	Missing information	There is no information about the purpose of the transfers and how to use it	Not treated		90,91	18,39
Q4 - clarity	55	Usability	If clicking on the arrow, the menu with the two choices does not open	New			
Q4 - clarity	56	Usability	When considering timeseries, other units such as ML or GL could be more commonly found. The other units may increase the burden of users to convert the units in their datasets and could become potentially a source of errors.	New			
Q4-clarity	57	Missing information	It is unclear whether users need to keep the headings for the template	New			

			for the tool to identify timeseries values				
Q3- data parameterization	58	Usability	The warning message to raise awareness about the need to use round values is delayed and could be missed by a user while appearing.	New			
Q4- clarity	59	Usability	Management issue when considering more than one transfer for a reach	New			
Q3-data parameterization	60	Usability	Users may not be aware they should always provide a numerical value	New			
Q3 -data parameterization	61	Risk of error	There is no awareness or warning to prevent users from setting the parameter even in unregulated reaches. The water balance accounts for environmental water even in reaches without dams.	New			
Q3 -workflow	62	Missing information	Metadata are not explicit enough about how to use the datasets	Partial	How some datasets could be used in briefly mentioned but the wording used is too ambiguous to raise awareness of other ways to use datasets - still need to be improved	11,71	27,54

Q3-learnability	63	Missing information	The text for 'Run' may not be explicit enough and the purpose for selecting more than one scenario is unclear	Partial	Considered but still ambiguous and still need to be improved	105	20
Q3-process	64	Usability	Values for water productivity and crop value are delayed and only appear while hovering over the pie charts. Some users may not be aware of delays for the information to appear, reducing the use of the results and potentially the perception of purposefulness of the tool	Not treated		50	
Q4- model validation	65	Usability	For datasets ending before 2000s, the model could not generate comparative data between the flows estimates from the model and observed data. The purpose of such datasets is unclear, and their use could prevent a user to consider other datasets as thinking the tool is not working	New			24
Q4-clarity	66	Usability	There is an apparent inconsistency as only two scenarios are selected, and more than one scenario results appear	New			
	67			Not treated			42,46,80

Q4-transparency		Missing information	There is no information about the purpose of comparing flow metrics, the source for the model and about how data were estimated and how to interpret the results provided			33, 101,102,126, 128	
Q4-transparency	68	Risk of error	The wording to define the information provided by the heat map could be confusing. The description mentions absolute percentage of change against the baseline scenario. As relative to a baseline, the percentages could not be absolute values.	New			
Q4-saving	69	Usability	Data are automatically saved but users may want to feel sure to save their work	Partial	The icon for saving is visible. But still, there is no evidence that clicking on it could ensure the work has been saved. Still to be improved.		34
Q4-saving	70	Usability	Users could rapidly struggle to manage the number of models and scenarios created. There are no other options to either keep or delete models/scenarios	New			
Q3 - task workflow	71	Usability	There is no awareness of the scenario edition task status, which could increase a user mental load	Not treated			43,95

Q4-clarity	72	Risk of error	The position of the figure for irrigation use at the bottom of the page could be difficult to consider, as users must scroll down to visualise it.	New			
Q3 - learnability/	73	Usability	When considering inter-basin water transfers, the model does not allow for the extension of a basin boundary to include another basin or to compare more than one basin model and associated scenarios together. In the example of the Brahmani River basin, it is not possible to consider the Mahanadi and Brahmani River basin together.	New			
Q5 - practice	74	Missing information	The lack of information about the targeted audience make it difficult to consider if the features provided as sufficient and reflective of a professional setting and expected skills to use. If considering expert modelers and policy makers, the tool is too simple and rigid in its representation of a problem, options to evaluate, and uncertain	New			

			conditions to be able to inform planning decisions. As for novices, there is no evidence of relationships between the process considered in the tool and the planning process. Also, there is no guidance and feedback to support learning, the development of critical thinking, and awareness of the skills to design and evaluate a plan.				
Q3 -workflow	75	Usability	There is no possibility to go back to the Basinpedia to access the contextual information following the creation a basin model. Land use information could still be accessible under the scenario editor, but the other contextual information per reach is no longer accessible.	Not treated			42
Q3-data parameterization	76	Missing information	There is no evidence of compulsory information to set a minimum under the scenario editor.	Not treated		55	50,38
Q4-transparency	77	Missing information	For results - gauges, there is no indication that the model validation could only be made when considering the baseline scenario representing a current	New			

			situation in a basin or a past situation (depending on the time range considered when using historical datasets)				
Q4-model validation	78	Missing information	The user could not access the documentation under the confluence page without authorizations. In addition, the home page does not provide a summary of the model architecture, main built-in models and their relationships in the tool, and expected behaviours from the tool based on potential priority orders and processing rules. Such a lack of minimum information could prevent users understanding of the tool behaviour.	Not treated		55,74,75,79, 80,81,114,11 5,123,124,12 6,128	81
Q4 - clarity	79	Risk of error	A user may not be aware that the statistical estimates are averaged over a selected time range when running the analysis. There is a need to clarify the influence of the time range on the results	Not treated		26	
Q4-model validation	80	Risk of error	The information in the water balance for the consumed demands appear unrelated with the values computed manually, summarised in the scenario editor	Not treated			4

			table for demands, and derived from the timeseries.				
Q4-clarity	81	Usability	The timeseries for the "total extracted demand" and "requested demand" are similar	New			
Q4-clarity	82	Risk of error	Users may think values are related to domestic consumption only. It is possible that Industrial uses could be included (as the case for the timeseries for "domestic return")	New			
Q4-clarity	83	Risk of error	The domestic return timeseries appear to include industrial water. Which is not clear from the heading.	New			
Q4-clarity	84	Uncertainty	For specific applications and contexts, the domestic demand return could be needed, independently of industrial water demands.	New			
Q4-validation	85	Risk of error	Including the industrial demand in the % return may lead to an overestimation of the water returned to surface waters as industrial users may recycle the water they demand and the annual percentage return could be less compared to the domestic one.	New			

Q3-data parameterization	86	Missing information	There is no clear information related to the possibility to define a water return from irrigation uses using the action command under crops in the scenario editor. The purpose of providing timeseries for irrigation return could be confusing too as implying that the parameter may need to be emphasised when editing a scenario.	New			
Q4-transparency	87	Missing information	When considering parameters under actions for the crops and for water, there is no clarity regarding what is considered for the different parameters and how to set them.	Not treated		62,63,66,67	20
Q4 - model validation	88	Risk of error	Values from irrigation uses under the water balance are inconsistent with the ones calculated from the timeseries.	Not treated			4
Q4-transparency	89	Missing information	In the water balance table, it is unclear what the final storage is about and how it is calculated. The values do not seem to account for evaporation loss and some of them rise whereas other dramatically decrease.	New			

Q4 - model validation	90	Risk of error	The map for the blue water scarcity is not related to the values provided in the water models. It appears that the models used for identifying different scarcity levels are not related.	Not treated			4
Q3- data parameterization	91	Risk of error	A user may be discouraged to use climate change historical datasets due to the statistical values obtained from the comparator use.	Not treated		28	
Q4-clarity	92	Usability	It is unclear whether a user will notice the link to more information as it is presented	New			
Q4- model validation	93	Missing information	Some of the links to datasets could not be found or are not provided	Not treated		48	20
Q3 - data parameterization	94	Usability	Users could be discouraged to wait for the process to be completed when using the comparator to select a rainfall dataset.	Not treated			34,50,82
Q4-model validation	95	Missing information	There is no accessible information about the built-in models and their rationale to be considered in the tool compared to similar models.	New			
	96			New			

Q4-model validation		Missing information	If considering the GR4J model to compute rainfall runoff data, as data are calibrated based on at least monthly values, it is unclear whether the model is appropriate for calibration purpose.				
Q4-model validation	97	Usability	If considering a professional audience, it is possible the built-in models and datasets may not be satisfactory and could limit interests in the tool.	Not treated		72,87,88	9,36,47,53,60, 64,66,75,84
Q4- model validation	98	Usability	The mix of macro-level features with micro-level ones could be confusing for users and question the purpose of the tool. From the home page, the model appears to allow for a basin exploration but not fitted for local assessment.	Partial	Partially considered through restricting the number of reaches and level of resolution when creating a basin model. Still require some improvements		15,69,71
Q4-clarity	99	Risk of error	It is unclear whether the figure for irrigation use is a summary for all reaches, for reach 7 as placed below it, or for reach 1 as reflected by the legend.	New			
Q4-clarity	100	Risk of error	The graphs representing crop yields, for each crop, could become difficult to read when considering longer time range and more crops.	New			

Q4-clarity	101	Risk of error	The threshold values may not be visible for users.	New			
Q4-transparency	102	Missing information	There is no information related to the storage reliability indicator, choice and reference for the threshold value, and indications in how to use the indicator.	Not treated		146	72
Q5 -confidence in results	103	Missing information	There are no considerations of other agricultural activities in the model such as rainfed agriculture, forestry, fisheries. Also, the model focuses on food production, but crops for energy production may need to be added with associated water uses, yields, and incomes	Not treated		58,59,60	
Q5 -practice	104	Missing information	Costs for irrigation are not considered. Similarly costs and benefits from other sectoral activities are not evaluated by the tool, which could limit some interests for professional uses and plan design.	New			
Q5 -confidence in results	105	Missing information	Storages are considered in the tool, but their implications for land suitability and availability for irrigation developments is not considered, which could lead to	New			

			overestimates in terms of the potential for irrigation developments to occur.				
Q5 - customisation	106	Missing information	There is no information in how to potentially use the datasets provided to account for land uses and availability when considering socioeconomic developments, which could bring interests in the use of the tool.	Partial	Considered to some extent related to land use datasets and mention of 'contextual' uses. But lack of clarity about what 'contextual implies.	60,68,71	44
Q5 -confidence in results	107	Missing information	Livestock water uses are not considered in the tool, which could leads to overestimations of water availability in a basin when considering significant livestock populations	Not treated		84	
Q5 - representation of SES	108	Missing information	No management options are provided for water treatment, alternative water supplies, innovations to recycle water, rainstorm harvesting	Not treated			22
Q5 - customisation	109	Missing information	Some indicative values about the nutritious content of crops is provided, but there is no further uses of that information to evaluate food security and nutritious supply to animals and the population in a basin	Not treated		64,86	

Q5 - representation of SES	110	Missing information	Flood security is not directly considered in the tool. Hydrological data are provided but the effectiveness of storages to manage flood events or alternatives for that matter are not considered in the tool.	Not treated		53	
Q5 -confidence in results	111	Missing information	From the water balance, there is no apparent considerations of water consumptions or reserve for aquatic (and terrestrial systems aside from irrigated crops) systems. Similarly, and already addressed in some of the previous issues, the use of the index of alteration is unclear. As it is the tool poorly account for evaluating ecological sustainability.	Not treated		87,88	
Q5 - customisation	112	Missing information	Water quality is not directly addressed in the tool. The Basinpedia provides some indications related to the status of water quality in the basin. Considering assumptions in how to use that information to account for water quality when considering the total amount of water available for different uses	Not treated		89	

			would be useful to think about water scarcity in a basin.				
Q4-transparency	113	Missing information	Rules to release water for hydropower production are unclear and appear linked to water allocations for drinking, irrigation, and environmental uses, than related to the demand for electricity generation.	Not treated		62,82, 114-117,119,121	
Q5 -confidence in results	114	Missing information	Limited options to manage the supply, and far less to manage the demands could be assessed using the tool	Not treated			22
Q4-clarity	115	Usability	Administrative boundaries, even though not explicit mentioned in the legend, are represented by red dot lines on the map under the scenario editor. There is a need to make these lines more visible as could be potentially of use for a user to consider interstates/inter districts water management decisions and their potential implications for upstream/downstream users.	New			
Q5 - customisation	116	Missing information	A user may want to evaluate joint management strategies or the potential risk of conflicts from	New			

			planning decisions when considering a basin water shared by different states/districts. There is no guidance in how to consider administrative boundaries in the tool.				
Q5 - customisation	117	Missing information	Except in rare exceptions, there is no possibility to extend the boundary of a basin to another one from where water could be extracted or conveyed. There is no guidance in how to consider joint management strategies or risk of conflicts when considering inter-basin or transboundary basins in the tool.	Not treated		91	
Q5 - representation of SES	118	Uncertainty	Some stakeholder groups, including ecological systems, may be partly represented or totally absent from the tool. According to a case study of interest, the absence of some groups may reduce the use of the tool	Not treated		101, 102, 126, 128	64
Q5 - representation of SES	119	Uncertainty	Water supply and water demand management options are still limited in the tool and mostly focused on irrigation production and developments. Most of these options remain infrastructural and	Not treated		59,67,88,89, 93,94	22

			related to supporting the reliability and efficiency of the water supply from surface waters.				
Q5 - representation of SES	120	Uncertainty	Only irrigation development scenarios and to a lesser extent urbanisation and industrialisation scenarios could be represented in the tool. Other sectoral activities and ecological sustainability scenarios are not considered in the tool.	Not treated		110	
Q5 - representation of SES	121	Uncertainty	The tool allows for the consideration of climate change projections but other future possible changes, related to different political, social, economic, legal, ecological, and technological drivers, influencing a basin from the outside are not considered by the tool.	Not treated		58,59,65,66, 83, 110	
Q5 - customisation	122	Usability	There is no guidance in how to consider and assess scenarios considering multiple time range. As it is, the tool does not allow for the exploratory modelling but still as a forecasting model, even though allowing for the consideration of climate change projections.	Not treated		56	

Q2 - user feedback to developers	123	Usability	If willing to inquire about the potential for the developers to include specific features in the tool, the feedback button may not be sufficient, as mostly dedicated to document issues while interacting with the tool.	Not treated			55
Q2 - developers feedback to users	124	Missing information	There is no evidence of existing Q&A page or link to consider some common issues and means of resolution	New			
Q2 - developers feedback to users	125	Missing information	There is no evidence that feedback has been effectively received and the developers will consider an issue or inquiry	Not treated			58
Q2 - developers feedback to users	126	Experimental	There is no option for a user to be able to discuss issues with other users and the developers, which could improve communication and encourage more interactions with and innovationfs for the tool	Not treated			61

Multi-Scale Scenarios For Robust And Adaptive Planning: Hypotheses Testing Of Their Merits With Key Interest Groups For Informing A Framework

C. Supplementary Material – Chapter 5

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A– Walkthrough used in the interview process.

Scenario planning process is presented in a three-slide PowerPoint document (see below). The first two slides focus on scenario development stage, listing possible activities and providing an example of scenario narrative related to the Mary River Basin case study. Participants were encouraged to engage to familiarize themselves with the process, using a preferred example, and invited to read the illustrative narrative before addressing the questions. The third slide highlights potential activities involved in scenario analysis stage, featuring an example of scorecard displaying results within the context of water security in Norway. This example was selected as showcasing the use of scenario planning at two scales, International and National, highlighting the potential for using scenario planning at multiple scales.

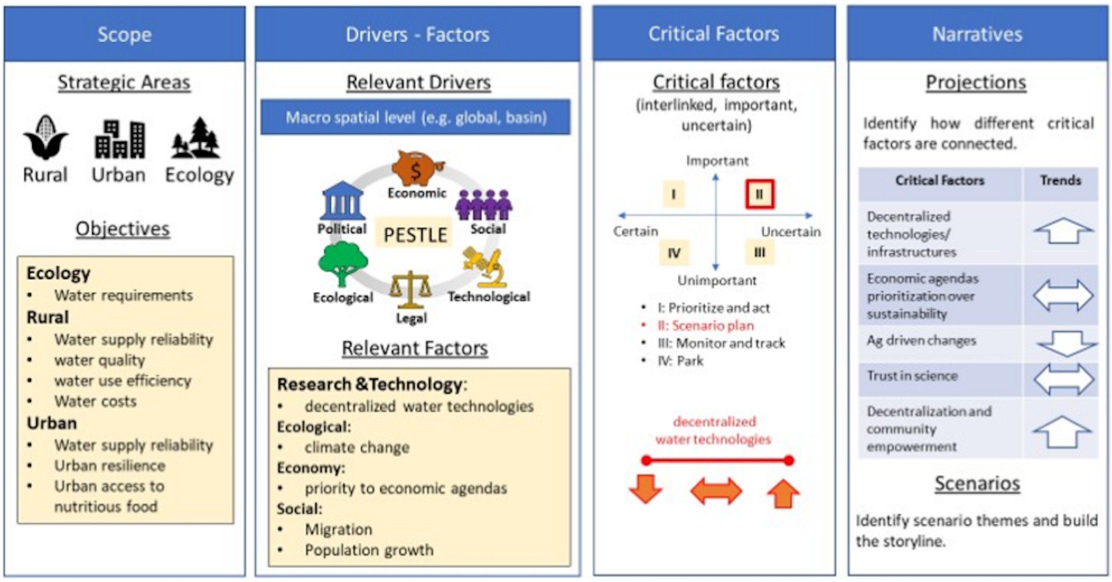

Figure A.1. *Illustration of activities for scenario development stage.*

The region's population has grown by 75%, from 4 million in 2021 to 7 million in 2050. Digital technologies and internet connectivity have advanced significantly, enabling a virtual presence for work, study and other activities. This regional lifestyle is supported by affordable digital health care, on-demand and affordable transport, greater acceptance of credible remote learning certificates and micro-credentials, and quicker and more streamlined freight services. Automation technologies take care of routine manual tasks allowing most workers to focus on providing knowledge and services. Subsequently, the need for physical presence in the workplace or classroom is reduced. Most workers have more flexibility in where and when they work and benefit from shorter workdays to focus on personal wellbeing and community services. As a result, a growing number of people choose to live in regional centres over expensive and crowded cities.

Decentralised water technologies play a crucial role in the regional centres to support water supply and treatment and improve climate resilience. High capital expenditure on new infrastructure has placed an initial strain on government budgets. However, the ongoing operating costs are reduced by more efficient and connected systems. Combined with decentralised energy systems, these flexible and sustainable options replace the need to build large water delivery and treatment infrastructure. The costs associated with new infrastructure mean the rollout is not uniform across the region, with faster-growing areas benefit ahead of others.

Critical Factors	Trends
Decentralized technologies/infrastructures	⇧
Economic agendas prioritization over sustainability	⇔
Ag driven changes	⇩
Trust in science	⇔
Decentralization and community empowerment	⇧

With more people living in the regional centres, growing numbers of people became engaged in regional issues and demanded change in how decisions are made. A system of transparency, clarity and acceptance of decision-making between institutions of governance at the central, regional and local levels is established, and participatory decision-making becomes the norm. Supported by increased local revenues and participatory budgeting, local councils and NRM bodies develop strong partnerships with communities, industries and research institutes to develop and support holistic development goals. This shift from coalitions around political lines to coalitions around issues still presents challenges associated with conflicting values and priorities. However, communities are empowered to engage in water management and negotiate positive outcomes at local scales.

Disaster risk management focuses on community-based activities such as community assessments of hazards, vulnerabilities and capacities, and their involvement in planning, implementation, monitoring and evaluation of local action for disaster risk reduction.

With socio-economic and ecological improvements, new decentralised industries and services emerge in the region, attracting a seasonal and perennial population around the regional centres.

By 2050, a more decentralized and collectively empowered society emerges in the Mary and SEQ region.

Figure A.2. *Illustrative scenario narrative based on the Mary River Basin case study.*

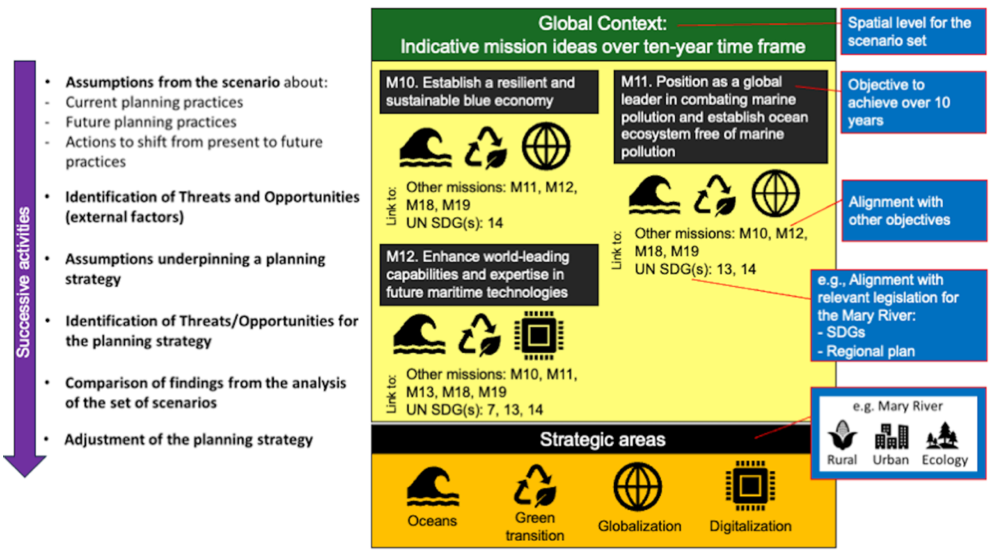

Figure A.3. *Example of activities for scenario analysis stage (left) and example of output as a scorecard in the case of water security in Norway (right)(Adapted from Gunashekar et al., 2021, p.30[7]).*

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[7] Gunashekar S, Gloinson ER, Dunkerley F, Virdee M, d'Angelo C, Feijao C, Ali G-C, Skjoldager M, Skjold A. Addressing societal challenges in Norway (pp.76) [Foresight study

B – Semi-structured interview questionnaire.

The questionnaire used for semi-structured interviews comprises 13 questions, articulated around the walkthrough provided in A. Questions related to the walkthrough generally explore societal and organizational responses to changes and decisions. Specifically, inquiries regarding societal responses gauge the acceptability of decisions among local stakeholders. Questions related to organizational responses center on the feasibility (both internal and external) for water management organizations to implement decisions locally and sustain them over time.

Questionnaire:

1 Would you like to tell me more about your work and responsibilities, as related to water planning and management?

2 Do you have a previous experience with scenario planning or other methods to think about the future? If yes, would you like to tell me more about your experience?

[Walkthrough: slides 1 and 2 Description of some activities involved in scenario development and provision of an example of scenario narrative]

3 Do you think the level of insight derived from the scenarios is sufficient to judge of the acceptability of decisions for people? Could you explain your answer?

4 Do you think the level of insight derived from the scenarios is sufficient to judge of the feasibility of decisions for water managers and operators, responsible for their implementation? Could you explain your answer?

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for the Research Council of Norway]. Santa Monica (CA): RAND; 2021. Available from: https://www.rand.org/content/dam/rand/pubs/research_reports/RRA900/RRA966-1/RAND_RRA966-1.pdf

5 To what extent do you think the level of details related to spatial/organisational scales would need to be improved?

6 Thinking of the activities involved, how could the level of details be improved?

[Walkthrough: slide 3 Description of some activities involved in scenario analysis and example of reporting of findings as a scorecard.

7 To what extent do you think the spatial level of the scenarios used is sufficient to judge of the acceptability of decisions for people? Could you explain your answer?

8 To what extent do you think the spatial level of the scenarios used is sufficient to judge of the feasibility of decisions for water managers and operators, responsible for their implementation? Could you explain your answer?

9 How could the activities involved could help reflect on the acceptability and feasibility of decisions?

[End of the walkthrough and consideration of general questions about the whole process.]

10 Can you think of examples when it would be useful to consider scenarios at fine spatial/organisational levels? Could you explain how it could have been useful?

11 For whom do you think fine spatial/organisational scale scenarios are likely to be useful? Could you explain your answer?

12 Thinking about water resources planning, what would be one or more good spatial/ organisational scale(s) to consider in scenario planning? Could you explain your answer?

13 Overall, what is your opinion about using scenario planning to think about the implications of planning decisions for people and water-related organisations at different spatial/organisational scales?

14 Would you be interested in participating in such a process? Could you explain your answer?

15 Would you like to add any comments that may feel important for this evaluation?

C – Recommendations from participants

Table C.1. *Recommendations for operating across multiple scales and associated stages in scenario planning process.*

Type of recommendations	Participant groups	Description	Where in scenario planning process
Resources	NGO, WP	Consider in advance the allocation of resources to support engagement in specific locations and the capacity to transition from one catchment area to another.	Setting
	WPs, academic, consultant	Establish a comprehensive strategic policy that guarantees consistency in processes while remaining adaptable to varying contexts.	Setting
Stakeholder engagement	NGO	Utilize a digital platform as an opportunity to engage and exchange knowledge with stakeholders.	Setting
	Consultant	Incorporate interfaces connecting individuals with key decision-makers to bridge decision-making levels at the local, regional, and state levels, including Local Governments (LGs) and Natural Resource Management (NRM) groups.	Setting

	Academic, HD	Consider questions related to representation and equity in decision-making to facilitate consideration of the necessity to include various stakeholders in decisions over time. Examples of such questions include: "what would happen under this scenario in your region?", "How would people respond?", "what does representation mean?", "does everybody get an equal voice?", "is it a good thing or not?"	Scenario analysis
Identifying relevant scales	WP, academic	Take into account legislative constraints and allocated resources for statutory authorities and organizations, constraining the extent of their operations.	Setting
	WO (manager), academic	Think about the system boundaries and the scales that need to be considered, taking into account the connections with other water systems, such as groundwater systems and related boundaries.	Setting
	HD, academic, WO (manager), community group	Considering capacity and time limitations, sample small-scale locations without aiming for perfect information. Identify spatial scales relevant to the impacts associated with different objectives. For instance, ecological commitments may necessitate considering	Setting

		larger scales than the basin level to accommodate protection commitments, such as those outlined in RAMSAR or World Heritage conventions.	
	HD	Take into account catchment levels when contemplating non-infrastructural interventions and their implications in addressing higher objectives.	Setting
	Academic	When considering scope and drivers activities, contemplate the extent of influence on specific drivers within a particular region and assess how many of these drivers have broader implications in terms of influence.	Setting; scenario development
	Community group, WP	Engage in discussions regarding the potential implications of changes in leadership across various influential entities within governments, government agencies, organizations, and communities. Identify relevant spatial scales and associated assets with key values to facilitate evaluations of the impact of these changes.	Setting; scenario development

Consistency across scales	Academic	Determine whether there is a need for consistency in methodologies to address issues, contingent on whether the matter can be effectively managed at the local level or necessitates involvement at higher decision-making levels.	Setting
	Academics, NGO, consultant, HDs	Identify mechanisms for incorporating values, and for balancing and aligning objectives, drivers, critical factors, and trade-offs at various scales, employing approaches such as the nested approach. This may include steps such as: 1) getting acceptance about the existence of a problem and its nature, 2) working through what the scenarios at macro and local scales will be and identify the ones that will deliver changes, 3) evaluating the impacts of that change at macro and local scales	Setting
	Academic	Clearly articulate who makes decisions, at what spatial levels, and whether it requires consistency across spatial levels or not.	Scenario development

	Academic	Discuss the alignment of objectives with other relevant plans and commitments to ensure their achievement, even when these objectives operate independently from water plans.	Scenario development
	Community group, academics, WO (manager), HD	Consider the scale of impacts resulting from interventions at various levels, including locality, river systems, and plan levels, along with their outcomes. Evaluating the benefits of interventions or the lack thereof, as well as identifying opportunities at different nested scales, can contribute to pinpointing where to implement interventions for an acceptable impact at scale.	Scenario development; Scenario analysis
	Academic, NGO	Engage in discussions with stakeholders to assess the extent to which conventional scenario narratives align with (future) local objectives, perceived risks, and values and address tensions arising from misaligned values and associated objectives, drivers, and trade-offs.	Scenario analysis
	NGO, academic, WP	Consider questions to reflect on threats and opportunities at different scales: e.g. what is Australia role and the implications of political	Scenario analysis; Setting

		cycles? Such a reflection could assist in identifying the scale of impacts over time and space.	

WP = water planner (States), HD = high decision-makers (States, Commonwealth), WO = water operator, NGO = non-governmental organization, LG = local government, NRM = natural resources management.

Table C.2. *Recommendations for considering finer scales in scenario planning process.*

Type of recommendations	**Participant groups**	**Description**	**Where in scenario planning process**
Stakeholder engagement	Academic, WP	Ensure a balanced representation, including motivations, values, and knowledge, to facilitate the identification of more balanced critical factors.	Setting
	Consultant, WO (manager), WP, HDs, academic, WO (strategic planner)	Identify and discuss with stakeholders and leaders of influence the validity of scenarios, the alignment of local objectives and the main drivers of change, and the feasibility of managing these drivers at the local level. This process may also involve designing or adjusting scenario narratives to make them more meaningful at the local level.	Scenario development; scenario analysis
	Consultant, HD	Engage in discussions with on-ground water professionals to assess the desirability of interventions and their feasibility for implementation, considering the local capacity.	Scenario analysis

Priority areas, objectives, and drivers	Consultant, academic, HD, WP	Allocate time to understand and agree on the objectives and identify who care about them before proceeding to identify critical factors.	Setting; scenario development
	Academic, consultant, NGO, WP	Clearly define the purpose of scenarios and articulate expectations regarding outputs to identify objectives and drivers. Provide specific details based on the type of scenarios to be developed.	Setting; scenario development
	Consultant, academic, HD	Consider incorporating more specific and disaggregated strategic areas, rather than broad categories like rural, urban, or ecological areas, to enhance clarity in understanding trade-offs.	Scenario development
	NGO, WP	Encourage the project team to reflect ont the setting, participants (including facilitators), constraints and their potential influence on the purpose of the process and activities related to the identification of objectives, drivers; and, ultimately, trade-offs.	Setting
	Academic, HD, NGO, WP, community group	Pose questions and prompts to engage stakeholders in discussions about what matters to them (values) and their perceived risks, as	Scenario development; scenario analysis

		well as how values might evolve over time. These questions aim to elucidate localized impacts that influence people's connections and values, thereby affecting perceptions of different risk levels. Additionally, address business owners with inquiries that clarify the implications of decisions for local businesses and the actions they take to address changes. Collaborate with the chamber of commerce and the local council to access information about existing and new businesses. Finally, interact directly with business owners to assess the alignment of local actions with planning decisions and their implications.	
Developing narratives	Academic, WO (manager)	Ensure a proper balance in scenario descriptions by ensuring that key drivers influencing different outcomes are represented. This approach helps prevent biases in thinking towards some aspects and objectives.	Scenario development

	WO (manager), WO (strategic planner), WPs, HDs, NGO, academics, LG	Ensure that the stakeholders' current situation, the types of changes, and the timing of events are coherent. Clarify the underlying logic for key relationships and concepts, such as defining 'self-sufficient communities' and outlining the process to achieve that state. Consider utilizing a theory of change to ensure a coherent narrative flow and identify key "pointers" related to crucial relationships and connections that influence changes. Additionally, frameworks like PESTLE and nexus can support holistic thinking, contributing to a balanced representation of key factors.	Scenario development
	Academic, WO (strategic planner), NGO, consultant, WP, HD	Use prompts to facilitate reflection on the intended achievements of a scenario, guiding the consideration of details to be incorporated into the narratives.	Scenario development; scenario analysis
	Academic, WO (strategic planner), consultant, NGO, LG, WP	Ensuring the inclusion of pertinent details to comprehend the finer levels, including demographic data and economic information (refer to Appendix 8), described in a manner that	Scenario development

		resonates with the lived experiences of organizations and stakeholders.	
	Community group, academic, HD	When detailing specific interventions at key locations, such as dams, where documented information is available, ensure a comprehensive description that outlines their implications for water and related systems.	Scenario development
	Community group, academic, WO (strategic planner), NGO, HD, WPs, LG	Provide a description of key organizations (related to the participants) or people responsible for behavioral changes, outlining their roles in influencing changes. Use case examples to personalize and illustrate the impact of these entities on desired changes.	Scenario development
	WO (manager)	Take into account more reactive actions, particularly in the context of disaster risk management, and explore the implications in terms of overall management, including recovery efforts, as well as their impact on other decision-making processes.	Scenario development

	WP	Assess the content and language of the narratives through discussions and feedback sessions with leaders of influence.	Scenario analysis
Thinking about future events	WP, HD	Incorporate transitional scenario descriptions, for instance, a scenario bridging the period between 2020 and 2050 (e.g., Medium Term), to maintain the logic and consistency of narrative descriptions. Pose questions that encourage participants to envision their desired outcomes over the next 20, 30 and 50 years, allowing them to actively contribute to the scenario design process.	Scenario development
	HD	Clarify upfront what you aim to achieve, where you are trying to go, and why you are trying to get there. This clarification is necessary to minimize the risks of misunderstandings and/or potential barriers to participation.	Scenario analysis
	Consultant, WP	Incorporate pertinent details within the scenarios to prompt stakeholders to assess the feasibility of implementing decisions and to contemplate the implications for them in terms of desirable	Scenario development

		impacts, opportunities, and threats. This includes considering the objectives of organizations and communities, as well as potential barriers and the consequences of changes on them.	
	Academic, community group, WP	Provide a summary that combines scientific and stakeholder knowledge concerning the implications of changes for various stakeholders and ecological systems. For instance, understanding the consequences of changes in flow regimes requires a grasp of historical and current knowledge about flows and factors that influence different users' needs. Additionally, mapping the varying levels of risks within catchments and utilizing scorecards representing a reviewing system can be beneficial. These scorecards may be applied at different timeframes throughout the duration of a plan or project.	Scenario analysis
	Consultant, HD, WP	Engage stakeholders in discussions to assess the plausibility of scenarios, identify the essential conditions for different	Scenario analysis

		relationships, and explore the feasibility and timing to implement interventions.	
Testing assumptions	WO (strategic planner), academic, LG, consultant, WPs, NGO	Improve the level of details in scenarios to ensure a deeper understanding of the level down and be able to compare scenarios against each other and test planning assumptions.	Scenario development
	Academic, HD, WO (strategic planner)	Instead of improving the level of details in scenarios, use questions to foster reflection and discussions about the implications of scenario descriptions for local contexts. For example, ask questions such as: “What would happen in this scenario in your region? how would you all respond?" These questions could reflect successive reviews: 1) For a first plan: “what water should be allocated to the natural system?” For the remaining water, “how should it be divided between other water users?”. 2) For a second water plan, when considering and starting to understand the impacts of changes. For example, it becomes more difficult to decide water allocations when realizing less water is available for the environment and, therefore, other	Scenario analysis

		users. Or when considering transfers from water-rich areas. "Are there more resources available for consumptive use?" "How can they be allocated?" "Are ecological systems still the same and have the same water requirements as previously?". Questions could also prompt reflection on assumptions (including planning) behind intervention choices in terms of no-regret level of investment and levels of uncertainty, for example.	
	NGO, HD, WP	Use questions to stimulate consideration of the implications of disruptions and emergent events on attitudes, behaviors, values, objectives, and decision-making. Collaborate with participants to co-design a theory of change, using questions to guide discussions on where efforts should be concentrated to influence meaningful changes.	Scenario analysis
	Academics	Encourage thinking outside the box and initiate discussions about the enablers that can empower the participants/stakeholders to drive changes within their environment. Use questions to guide participants in thinking beyond legislative, institutional,	Scenario analysis

		operational barriers, such as: "Do your current institutional arrangements allow you to do that? And why not?", "What would you need to change about your behavior or the way that you interact or what institutions are in the room?"	
	WO (strategic planner), academic	Compare the scenarios with (RCP) projections and facilitate a group discussion to explore the implications of these projections on the ground under various scenarios. Clearly articulate the rationale for selecting different climate scenarios and elucidate the assumptions behind them.	Scenario analysis
	WO (strategic planner), academics, HDs	Provide clarity on thinking processes and associated assumptions when contemplating the sequence of possible events and their timing. This ensures a transparent evaluation of the plausibility of scenario descriptions, helping to avoid analytical errors during the testing of assumptions.	Scenario development; scenario analysis
	Academic, WP	When considering threats and opportunities across time with stakeholders, initiate discussions by introducing a potential threat	Scenario analysis

		or issue. Prompt participants to contemplate factors influencing the issue and encourage them to summarize their thoughts through a conceptual diagram. Utilize prompts such as: "To what extent do you think a water plan is likely to change in the future? Are there threats/opportunities (e.g., developments, other pressures) coming up on the horizon for a particular catchment?"	
	WO (strategic planner), WP	However, for the examination of strengths and weaknesses, it may be beneficial to conduct private discussions, or involve interfaces and leaders of influence. Alternatively, direct discussions on strengths and weaknesses could be appropriate when addressing future challenges at a regional scale. Tailor the approach to the specific context and objectives of the analysis.	Scenario analysis
	WO (strategic planner), community group, academic, WP, HD	Ensure the participation of key individuals in the discussions to attain the requisite level of detail needed for understanding potential outcomes under different scenarios. Having the right people in the room is crucial for identifying problems, and it	Scenario analysis

		facilitates the clarification of how planning objectives and interventions align with local contexts.	
	Community groups, academic, NGO, WO (strategic planner), WPs, HDs	Incorporate positive and negative case illustrations, maps, and other relevant materials tied to people's professional and/or personal lived experiences. This approach serves to support thinking and discussions about the local implications of changes. Utilizing these tangible examples helps to reach the necessary level of detail for testing assumptions at local scales.	Scenario analysis
	HD, academic	Establish consensus on the existing planning practices and clearly elucidate the assumptions that underlie them before delving into discussions about future planning practices. This ensures a common understanding and a solid foundation for exploring potential changes and improvements.	Scenario analysis
	WO (strategic planner), community group, WO (manager), NGO, WPs, HDs	Encourage participants to reevaluate their perceptions of non-assumption by employing probing questions. Utilize frameworks like PESTLE to extend discussions beyond water-specific	Scenario analysis

		considerations and stress test assumptions. This approach allows for an examination of numerical values and their validity across diverse contexts and for various stakeholders. Additionally, it supports the inclusion of broader perspectives, encompassing economic and social impacts of decisions, beyond traditional water planning practices.	
	Consultant	Employ inclusive language when presenting scenarios to ensure that participants can readily comprehend and assess planning assumptions.	Scenario analysis
Performance and desirability of/advocacy for decisions	HD	Identify the alignment or misalignment of priorities and objectives, pinpoint areas of potential resistance, and evaluate the associated costs required to address any resistance.	Scenario analysis; Reporting
	WO (strategic planner), academic, NGO	Incorporate scorecards for each scenario, focusing on benefits rather than just costs, to comprehensively understand the implications and desirability of different interventions. Ensure	Scenario analysis

		that benefits are not limited to monetary values but account for non-monetary aspects, representing the holistic value of interventions. Such as not only the dollar value to savings from restoration projects to reduce erosion in terms of water treatment costs or dam management, but also in terms of tourism value, people health and wellbeing. Establish multiple scorecards with different timeframes aligned with the purpose of the planning process, reflecting the varying paces of changes for different stakeholders and perceived levels of risks.	
	Consultant	Scorecards or other reporting media should offer visibility into how various strategic areas and missions articulate and align with objectives across different scales.	Reporting
	Consultant, WP	Engage experts such as economists throughout the planning process to translate findings into a compelling language that can influence decisions. For instance, use an 'asset' based language to	Reporting

		construct a business case that resonates with funders, accountants, and engineers.	
	HD	Report community satisfaction and effective outcomes of policies rather than scorecards. While scorecards may describe expected outcomes, focusing on community satisfaction ensures that policies deliver meaningful and impactful results that genuinely meet the needs and preferences of the community.	Reporting
	Consultant, WO (strategic planner)	Consider local indicators to monitor changes and performance. For example, frameworks to identify sustainable indicators for catchment management such as Walmsley's (2002)[8] framework. Additionally, use the scenarios as a warning system to monitor trajectories and allow for adjustmentst if necessary and feasible.	Scenario analysis

[8] Walmsley JJ. Framework for Measuring Sustainable Development in Catchment Systems. Environmental Management. 2002;29(2):195–206. https://doi.org/10.1007/s00267-001-0020-4

Shared agreement on solutions	WO (strategic planner)	Consider simulation events with stakeholders to explore different scenarios, disruptions and surprises, enabling participants to consider actual and necessary resources and interventions required to address future changes.	Scenario analysis
	WP, HD, NGO, consultant, WO (manager)	Co-design process to evaluate the implications of scenarios, test assumptions and trade-offs, identify relevant interventions and compensation mechanisms. Such a process is expected to ensure the transparency of processes, foster a shared understanding of decisions and their desirability.	Scenario analysis

WP = water planner (States), HD = high decision-makers (States, Commonwealth), WO = water operator, NGO = non-governmental organization, LG = local government, NRM = natural resources management.

Table C.3. *Suggestions to improve the level of details of scenario narratives.*

Recommendations	**Participant groups**
Types of industries supporting economic outcomes / employment profile in the region/ consider the implications of tourism (including opportunities).	Academic, consultant, WO (strategic planner), water planner, HD
Specify under specific contexts the implications of population growth for urban/rural sprawl, services, infrastructures, local resources, technology, and implications for water uses and needs.	All
Describe the main agencies that need to be involved to provide information as well as agencies for supporting understanding and influencing social outcomes.	WOs (strategic planner)
Have something about what we now know about innovations that would be tried out or just implemented and their implications for water resources.	Academic, consultant, HD
Have descriptions about power unbalances, how they would be managed, and who gets the final decision.	Academic, community group, HD
Describe who are influential individuals and leaders of influence in communities, organizations, governments and what are their values (to capture the motivations for changes).	Academic, WP
Indicate important legislative changes and how they would happen.	HD
Indicate who would finance specific activities explaining changes, who would be involved, and how the costs of changes would be distributed.	HDs, consultant

To better account for how people could respond to decisions and changes, consider describing what is motivating people, what their lived experience is (especially, backed by recent history), how diverse their community is, and provide demographic key information.	NGO, WPs
For the environment, just mentioning ecological impacts under climate change is not enough and more details are necessary to understanding the implications of decisions for ecological systems. Provide information about flow regimes, basin infrastructure, water uses and recreational use. In particular, provide insights about economic benefits from environmental flows rather than the economic benefits as a whole.	Academic, WO (manager), HD

WO = water operator, HD = high decision-makers, WP = water planner, All = all participant groups

Table C.4. *Suggestions for testing assumptions during scenario analysis stage.*

Recommendations	**Participant groups**
Clarify upfront what you are trying to do, where you are trying to go, and why you are trying to get there to avoid misunderstandings.	HD
Ensure agreement about what the current planning practices are and explain assumptions underpinning them before discussing future planning practices.	HD
Summarize scientific and stakeholder knowledge about the implications of changes for people and ecosystems.	Academic, community group
Consider positive and negative case illustrations, maps, etc. to link to lived or professional experiences at local scales.	Community group, academic
Use prompts to think about the implications of scenario descriptions for local contexts and to identify no-regret levels and unacceptable levels of investment.	NGO, academic, HD
Consider co-designing a theory of change with stakeholders to identify where efforts should be focused to influence changes.	WP
Use prompts to facilitate reflection about barriers such as: "do your current institutional arrangements allow you to do that?", "why not?", " what would you need ?"	academic
Clarify the assumptions behind projections (RCP) and discuss their implications for local contexts under the different scenarios.	WO (strategic planner), academic
Consider threats and opportunities across time with stakeholders using prompts and let the participants summarize	WO (strategic planner), HD, NGO, academic, WP

their thinking process as a conceptual diagram. For threats and opportunities across time, prompts could reflect a planning process with successive reviews.	
Consider a full SWOT analysis either directly (e.g., discussions at regional scale) or with interfaces/leaders of influence (for discussing more privately strengths and weaknesses)	WO (strategic planner), WO (manager), WP, local government
Challenge the participants' perceptions of non-assumptions using prompts or building on frameworks (e.g., PESTLE) to think beyond water and account for more holistic perspectives and implications for different stakeholders.	Consultant, academics, HDs, WO (strategic planner)
Use an inclusive language to support people understanding and connection with local contexts.	WPs, consultant, HD
For transparency and achieving consensus, consider a co-design approach to scenario analysis and identification of future pathways. Simulation events could be considered (including disruptions and emergent events) to facilitate scenario analysis.	HDs, WP, consultant, NGO, WO (manager), WO (strategic planner), academic

WO = water operator, HD = high decision-makers, WP = water planner, All = all participant groups

***Table C.5**. Generalities when considering participatory processes.*

Type of recommendations	**Participant groups**	**Description**
Stakeholder engagement		
Guiding principles	HD	Principles developed by the participant for including diverse voices: 1) leadership and creating leaderful communities, 2) building trusted relationships, 3) making sure you have clarity of purpose, problem definition and joint-discovery, 4) time flexibility and using windows of opportunity to progress change and change management, 5) demonstrating how decision making and reform implementation reflect the outcome of the engagement process
Resources	Community group, academic, consultant, HD	Plan ahead for resources dedicated to engagement and the evaluation of engagement outcomes. This encompasses the development of water literacy programs aimed at enhancing stakeholders' capacity to actively contribute to decisions. Water literacy should be programs should be initiated first, before expanding across the regions where changes are being contemplated.
	Community group, academic, consultant, WO	Explore and create diverse engagement methodologies, guides, and communication mechanisms to facilitate effective engagement with stakeholders.

	(manager), WPs	
Inclusion of voices in decisions	Academic, LG, WO (strategic planner), consultant, HDs, WP	Ensure representation from various stakeholder groups to foster a comprehensive whole-of-systems and stakeholders' perspective. This may include involvement from government agencies, health departments, educational institutions, agricultural entities, and private sector players.
	Academic, consultant, HD, WO (strategic planner), WP	Create a mapping of different stakeholder groups, delineating their objectives and motivations. This evaluation will help assess whether relevant stakeholders are present and ensure participants' commitment throughout participatory processes. The mapping process also aids in structuring processes and organizing groups within a room to facilitate balanced conversations and address power imbalances and tensions. The mapping should extend to identifying individuals based on their sectoral or disciplinary field for a more comprehensive understanding of perspectives.
	Academic, HD	Interact with interfaces to support effective engagement with communities.
	WP, consultant, LG	To ensure the effectiveness of processes and avoid artificial outcomes, identify and engage leaders of influence. Utilize questions to identify leaders, such as: "What genuinely motivates a person in their life and work?", "Why are they dedicated to their endeavors?".

		Typically, individuals driven by a commitment to improving others' livelihoods, thinking beyond personal interests to benefit their communities, and demonstrating authenticity in their actions make influential leaders. Look for those without excessive ego, who embrace vulnerability, self-reflection, and an understanding that outcomes may not always align with expectations. Positive leaders often possess a network of supportive individuals to navigate challenges. Make sure to consider the person with the loudest voice in the room, as it could be a leader, as planning decisions and their consequences matter significantly.
	HD	Engage high-level decision-makers, interfaces, and communities in processes to enhance understanding and advocate for or influence changes.
	WP	Steer clear of offering pre-determined solutions; instead, foster participation in processes and discussions centered around identifying issues and crafting potential solutions.
	WP	Minimize the influence of politics and media in processes to prevent external interferences and uphold effective education and contribution to the decision-making processes.
	WPs, WO (manager)	Explore and develop various approaches and engagement opportunities, such as consultations, to build stakeholder understanding and capacity. Tailor these initiatives to accommodate the diverse learning journeys and

		information needs of stakeholders, enabling them to actively participate in decision-making processes.
Facilitation	HD, WP	Ensure that information and education materials are communicated in a way that allows participants to build on their experiences. The content should be presented in a manner that is both simple and accessible, promoting understanding among diverse audiences.
	NGO, HD	Use prompts to guide participants in connecting with contexts, leveraging their experiences to contemplate consequences, and steering discussions back on track if they diverge. Craft questions that encompass a range of perspectives and are easily understood by the participants, ensuring a diverse and comprehensible exploration of the topic at hand.
Process	WPs	Clearly articulate the purpose of the process, detailing how and when participants will be engaged. Provide a comprehensive clarification of the roles and expectations from the participants. Consider using a theory of change to help structure the processes, providing a visual representation of the expected outcomes and the steps necessary to achieve them. This ensures transparency and alignment of expectations, contributing to a more effective and organized engagement process.

	WP	Identify and steer clear of areas and stakeholders with high-level risks for the project team and enhance the likelihood of successful outputs from processes.
Communication and reporting		
Transparency of processes	WP	Ensure a clear articulation of the different steps involved in the process, specifying who will be engaged and at what stage.
	WO (strategic planner), consultant, WP	Leverage simulations or collaborate with stakeholders to develop a theory of change, among other examples, to systematically test various future and development scenarios and alternatives.
	WP	Reflect on the realism of discussing certain interventions, especially costly ones like dams, and consider their feasibility for funding. If relevant, justify the inclusion of these interventions in processes in front of stakeholders, ensuring transparency and a clear rationale for their consideration.
	WO (strategic planner)	Be clear about the purpose of scenarios as reflective tools only.
Effective communication	WPs, HDs, LG, WO (manager)	Adopt language tailored to the intended audience and utilize relevant media and communication channels based on local resources, activities, and capacity. Steer clear of ambiguous or overly general language that may be open

		to different interpretations, aiming for clear and context-specific communication..
	HD	Ensure the timely delivery of findings/information to ensure their value.
	WP	Collaborate with stakeholders to identify effective and accessible ways to communicate and disseminate scientific information. Explore channels that may be more accessible than traditional written media, considering the preferences and needs of the target audience.
	WP	Avoid stereotyping stakeholder groups, such as First Nations, irrigators, or urban dwellers. Instead, recognize the diversity within these groups and understand how individuals and organizations within each category can be involved in processes.
	WP, HD	Condense and present information in an easily understandable format, such as a four-page brochure, accompanied by a conceptual model illustrating the process. This concise and visual approach enhances accessibility, making complex information more digestible for a broader audience. The inclusion of a conceptual model further aids in conveying the key aspects of the process in a clear and visually engaging manner.
	HD	Ensure clarity regarding the reasons behind findings and facilitate understanding of the consequences of decisions.

		Consider adopting a 'frame of consequences' approach, condensing information into a simple message that highlights the outcomes of various decisions. Tailor the communication strategy to identify appropriate intermediaries for conveying research findings, such as government agencies or departments, excluding media.
	Community group	Ensure decision-makers have been exposed to enough information to understand the implications of their decisions.

WP = water planner (States), HD = high decision-makers (States, Commonwealth), WO = water operator, LG = local government

D – Participants' perspectives on the illustrative scenario narrative to think about finer scales.

Stakeholder groups and corresponding numbers in the table represent the number of distinct participants who share similar reasons.

Table D. *Participants' perspective on the sufficiency of the illustrative scenario narrative, developed based on macro-scale factors, to think about finer scales.*

Reasons for perspectives	**Useful**		**Too high-level**	
Provide an idea of who and where people are in terms of changes (including governance) and technology.	Academics, water operators (manager and strategic planners), local government, water planners	8	Water operator (manager), local government, academic, NGO, water planner, high decision-maker	6
Support thinking about trade-offs, threats and opportunities.	Water operators (strategic planner), water planner	3	Academic, NGO, water planners	4
Support thinking about trends.	Local government, water operator (strategic planner), water planner	3	Water operator (strategic planner), NGO, water planner	3
Explain pathways to future changes.	Local government, water operator (strategic planner), consultant	4	Water operator (strategic planner), academic, NGO, high decision makers, water planner	6

Too water-focused, limiting understanding for some about how to influence changes.			High decision-maker, water operator (strategic planner)	2
Ambiguity in language to understand the implications and timing of events.			Academic, local government	2
Not enough details to understand local contexts and the consequences of changes.			Academics, water operators (manager and strategic planner), consultant, NGO, water planner	7
Lack of alignment with local/organizational objectives.			Community group, water operator (manager), NGO, consultant, water planner	5

E – Suggestions for identifying relevant scales.

Participants provided several recommendations for identifying relevant scales in the Scenario Planning at Finer and Multiple Scales framework. These suggestions revolve around three aspects: involving relevant stakeholders in process design, identifying critical boundaries (scales), and short-listing relevant scales.

1. **Including interface and leaders of influence** during the setting of scenario planning process to:
    a. Identify relevant scales and key values.
    b. Understand the implications of (future) changes.

Relevant interfaces and leaders are expected to bring insights into the broader context, helping identify critical scales and values. Beyond scales, they are expected to inform about relevant communication channels and methodologies to engage with stakeholders.

2. **Identifying critical boundaries (scale)** based on considering:
    a. Aspirations at different spatial scales.
    b. (future) threats and opportunities. Especially, threats associated with political regions and cycles for the feasibility of decisions.
    c. Non-management drivers and required level(s) of decision-making to address them.
    d. Legislative/organizational constraints.
    e. Natural and artificial water systems and connections.
    f. Infrastructural and non-infrastructural interventions and associated level of impacts.

g. The scale of impacts of different objectives.

The list aims to identify the boundary for different scales relevant to address planning purpose and provide an holistic understanding of the planning landscape.

3. **Short-listing relevant scales** based on:
    a. Team project's capacity and time.
    b. Existing case studies presenting diverse perspectives of local contexts.
    c. Opportunities for digital technologies for engagement and feedback.
    d. Risk for the project team to engage with stakeholders.

This stage helps focus on scales that align with the project's capacity, resources and potential for effective engagement.