Supplementary Material

# **Models integrated to Basin Futures**

## **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:

Where:

is the total available freshwater supply (m3),

is the blue water availability (m3),

is the water released for aquatic systems (m3),

is the supply reliability for irrigation (%) in year *y*, and 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:

And

Where:

and are the reliability of the supply (%) in a year *y* for the State or Jharkhand and the State of Odissa respectively.

## **Models considered (calculation-based solutions) to estimate the performance of adaptation pathways**

### **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):

Where:

is irrigated crop actual evapotranspiration over its growth duration *g* (mm/growing cycle),

is a time invariant crop coefficient, and

is the potential evapotranspiration (mm/month), with partial months included pro-rata with out of the total for month *m*.

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

Where:

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:

With irrigated land area considering a suitability factor given by:

Where:

is the total net incomes from irrigated crop production in 2000 USD$,

is irrigated crop yields (t),

is the irrigated planted area accounting for the potential impact of soil suitability (ha),

is the planted irrigated area without accounting for land suitability (ha),

is the crop price (USD$ in 2000/t),

, , and 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:

With:

water productivity (kg/m3),

1000 a conversion factor from t/m3 in kg/m3

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

Where 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:

Where and 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*) < *ET0*(maximum evapotranspiration in the absence of water stress):

* + *pET = ETa* (crop actual evapotranspiration) for *pET< ET0*
  + *pET* = mean monthly rainfalls for *pET > ET0*

Water demands for rainfed crops is given by:

Where:

is a rainfed crop actual evapotranspiration over its growth duration *g* (mm/growing cycle),

is a time invariant crop coefficient,

is the potential evapotranspiration (mm/month), with partial months included pro-rata with out of the total for month *m*.

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

Where:

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:

With:

Where:

is a crop yield (t/ha),

a crop maximum yield (t/ha),

is the maximum water demand for a crop, without soil moisture stress (mm)

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

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

Where:

is the total net incomes from rainfed crop production in 2000 USD$,

is the re-estimated rainfed planted area accounting for the potential impact of soil suitability on rainfed crop incomes (ha),

is the crop price (USD$ in 2000/t),

, , and 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:

When considering the two main state government in the Basin:

Where:

and 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 (kg/year) for a specific basin and the market price (USD 2000/kg) for its associated main native fish species used for food consumption.

Where:

is water bodies total area (ha),

is the area of surface water bodies (ha),

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 (USD 2000) for a decision point *t* and for the whole basin is given by:

Where:

and 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:

And

Where and are the net incomes from fisheries in Jharkhand and Odissa, respectively.

#### **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 m3/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 area growth rate from 2000 to 2025 and constrained by the command area. | The growth rate varies based on the chosen future scenario (business as usual or irrigation 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. | ICID, 2005 |
| 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:

Constrain to:

Where:

(km2) is the total land use area,

is the urban area (km2),

is the total cropland area (km2),

is the protected area within a reach (km2),

are other land uses and the remaining area after all other land uses (km2),

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

is grassland area within a reach (km2),

is the total reach area (km2).

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

Constrain to:

Where:

is the planted rainfed area (ha),

is the planted irrigated area (ha),

is the command area (ha),

is the total arable land (ha).

If , 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:

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 (km2) | 1 | 36 | 79 | 52 | 118 | 13 | 282 | Basin Futures |
| Protected area (km2) | 0 | 183 | 0 | 0 | 0 | 304 | 672 | Basin Futures and ICID, 2005 |
| Grass land area (km2) | 32 | 68 | 394 | 221 | 37 | 5 | 165 | Basin Futures |
| Cropland area in 2000 (km2) | 1588 | 3073 | 1349 | 3376 | 2882 | 1235 | 4026 | Basin Futures |
| Waterbodies area in 2000 (km2) | 20 | 121 | 29 | 232 | 1126 | 13 | 636 | Basin Futures |
| Reach area (km2) | 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 (SSPs) 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:

Where:

is the rural population at a period *t*,

*ssp4t* is the urban share based on SSP4 scenario,

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:

Where:

is the net incomes per capita (USD$/capita in 2000),

is the rural population at a time period *t*,

, are the net incomes from fisheries, irrigation and rainfed agriculture (USD$ in 2000) respectively.

* The State of Jharkhand:

Where:

is the net incomes per capita (USD$/capita in 2000) in Jharkhand

* The State of Odissa:

Where:

is the net incomes per capita (USD$/capita in 2000) in Odissa.

### **Urban incomes’ objective**

Urban incomes are reflected by changes in urban density ratio compared to a threshold value of 7963 inhabitants per km2, 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:

Where:

is the urban density relative ratio compared to the threshold value (inhabitants per km2)

is the urban population in a reach *r* for a period *t*

is the area covered by urban centers in a reach (km2)

Hydropower production ratio is given by:

Where:

is the relative change in hydropower production (MWh) between two consecutive periods.

is the mean annual hydropower production (MWh)

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

* For urban density ratio:

Where:

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:

Where:

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)

### **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:

Where:

,

is livestock mean annual water demands (ML)

is the mean annual irrigation water uses (ML),

is the mean annual D&I water uses (ML),

is the mean annual blue water availability (ML), including storages and D&I water return,

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 |

### **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 (m3/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:

Where:

is the annual blue water availability (m3/year),

is the mean monthly upstream inflow in year *y* (m3/month),

is the mean monthly runoff (m3/month)*,*

is the mean monthly water transfers (m3/month),

is the mean monthly storage volume (m3/month)*,*

*OFSr,t,m*is the mean monthly volume in on-farm water storages (m3/month),

is the D&I water return (m3/month).

Cropland green water availability (m3/year) is the sum of rainfed and irrigated actual crop evapotranspiration (ETa), estimated in their respective crop models (sections 2.1.1 and 2.1.2). To account for values in m3/year rather than mm/year, the respective land areas for rainfed and irrigated crops, according to irrigation development scenarios:

And

Where:

and are rainfed and irrigated crops mean annual evapotranspiration respectively (m3/year),

and are the mean annual evapotranspiration (mm) of rainfed and irrigated crops *c*, in a dedicated year *y*, respectively,

and 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.m2

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

Where:

is the annual cropland green water availability (m3/year),

is the mean annual irrigation water uses (ML)

1000 is a conversion factor from ML to m3

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 m3/capita/year, for the contribution of animal inputs to the reference diet (Xu & Wu, 2017), accordingly.

Where:

is the contribution of animal inputs to the reference diet (m3/capita/year),

is the frequency of occurrence of peak flood events in a period *t,*

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 (m3/capita/year)

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

Where:

is the mean annual Green Blue Water availability per capita (m3)

is the total population in reach *r* for timestep *t*.

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

Where:

is the scarcity index for population diet,

1300 is the fixed reference diet (m3/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 , the population diet is acceptable.

Conversely, for , 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:

Where:

is the mean FHI value for a period *t*,

is the number of months with a discharge over the bankfull one

is the total number of months in a time period.

* FHI values for the State of Jharkhand are given by:

Where:

is the mean FHI value for the State of Jharkhand.

* FHI values for the State of Odissa is given by:

Where:

is the mean FHI value for the State of Odissa.

# **Parameters used to set the scenarios for the Brahmani River Basin in Basin Futures**

## **Irrigated and rainfed crops’ water demands and yields**

### **Common datasets to estimate crop water demands, crop yields and crop incomes**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Rice** | **Pulses** | **Sugarcane** |
| ET crop coefficient | 1.2 | 1.25 | 1.1 |
| Planting months[[1]](#footnote-2) | June | June and October | June |
| Growing time (days) 2 | 120 | 110 | 365 |
| Moisture stress response factor 2 | 1 | 1 | 1 |
| Maximum yield (t/ha) 2 | 10 | 7 | 212 |
| Price in 2000 USD$/t 2 | $432.30 | $284 | $300 |

### **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).

* 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**

##### **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

##### **Planted areas (ha) with considering land suitability**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Reaches |  | 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 |

#### **bau2 scenario**

##### **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 |

##### **Planted areas (ha) with considering land suitability**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Reaches |  | 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 |

#### **irr1 scenario**

##### **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 |

##### **Planted areas (ha) with considering land suitability**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Reaches |  | 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 |

#### **irr2 scenario**

##### **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 |

##### **Planted areas (ha) with considering land suitability**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Reaches |  | 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 |

### **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 |

##### **Planted areas (ha) with considering land suitability**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Reach |  | 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 |

#### **bau2 scenario**

##### **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 |

##### **Planted areas (ha) with considering land suitability**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Reach |  | 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 |

#### **irr1 scenario**

##### **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 |

##### **Planted areas (ha) with considering land suitability**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Reach |  | 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 |

#### **irr2 scenario**

##### **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 |

##### **Planted areas (ha) with considering land suitability**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Reach |  | 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 |

## **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)[[2]](#footnote-3) | 700 / 8.4 |

Waterbodies area (km2) based on Basin Futures land uses for 2000

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Reaches | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| Waterbodies area in 2000 (km2) | 20 | 121 | 29 | 232 | 1126 | 13 | 636 |

In-stream reservoirs area (km2) 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 |
| 6 | 12 | 12 | 288 | 288 | 288 | 288 |
| 7 | 17 | 17 | 58 | 58 | 58 | 58 |

# **Problem framing for the Brahmani River Basin illustrative case**

## **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/km2, 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 m3/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. |

## **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 |

## **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 |

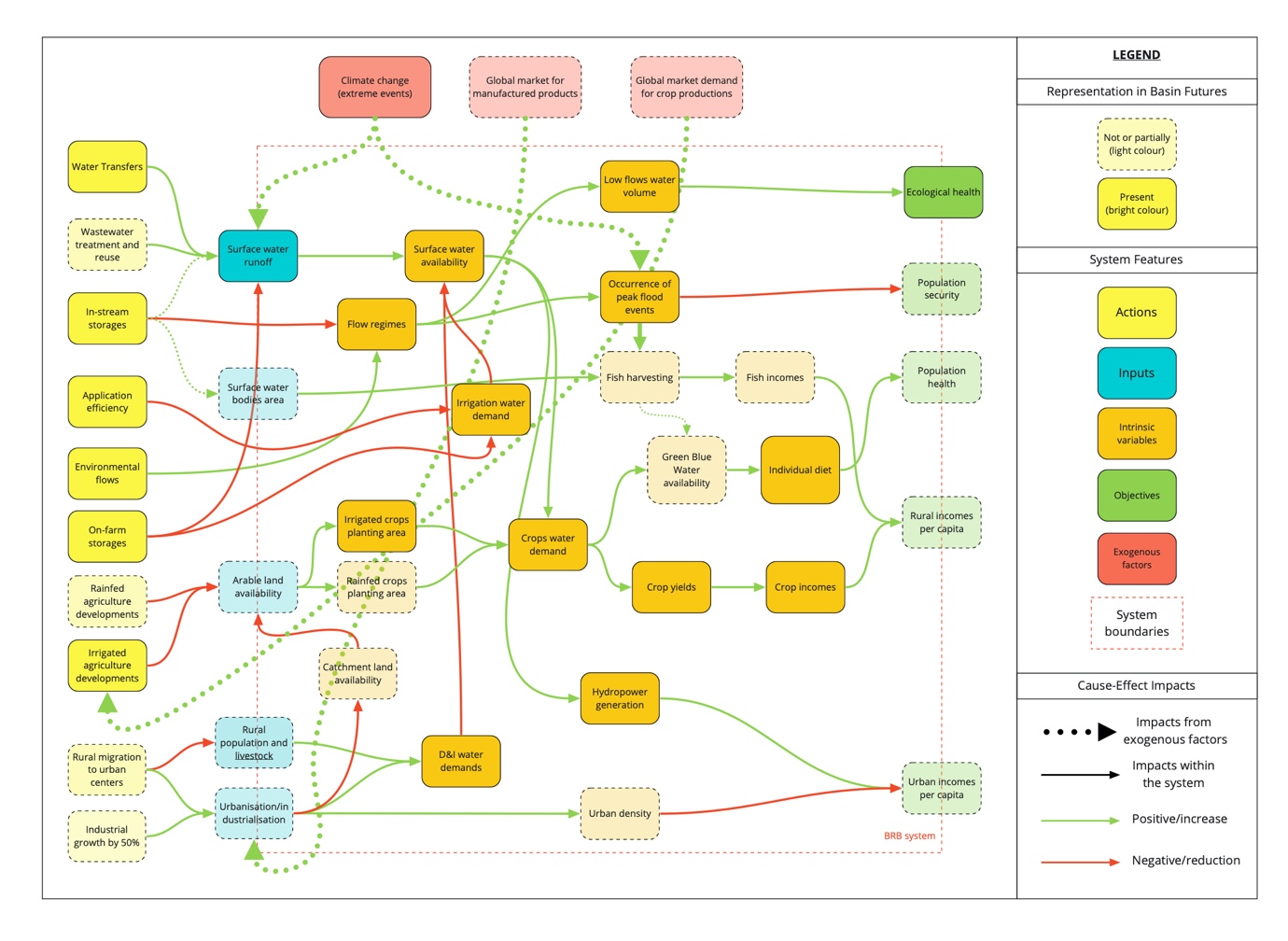
# **Additional results**

## **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 |

## **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.



## **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%. |

## **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 on-going 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 combination of actions do not fail under their future scenarios.

A picture containing chart

Description automatically generated

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1. Basin Futures datasets [↑](#footnote-ref-2)
2. Deb & Dey (2020) [↑](#footnote-ref-3)