**Scientific Study of Cauvery River basin, Coorg/Kodagu**

**Literature Review**

**Cauvery River**

The Cauvery River covers a drainage area of approx. 90000 km2 in the southern part of the Indian sub-continent. Cauvery rises at Talakaveri on the Brahmagiri range in the Western Ghats presently in the Coorg district of Karnataka state at an elevation 1341 m (4400 ft) above mean sea level. The catchment area of the entire Cauvery basin is 81,155 Sqkm including the other basin states of Cauvery river system and 34,273 Sqkm of Karnataka (Kavitha et al., 2017). The basin lies between North latitude 10o 05’ to 13o30’ and East longitudes 75o 30’ to 79o 45’. The principal soil types found in the basin are black soil, red soil, laterites and alluvial soil. The Geology of the drainage basin is principally formed from granitic gnesis, charnockites, granite, phyllites, slates, schists with chlorite, biotite, garnet and hornblende (Naqvi, Viswanathan, & Viswanatha, 1978; Ramakrishnan, 2009; Sathish, Sannappa, Paramesh, Chandrashekara, & Ventaramaiah, 2001). It flows through a densely populated area, from Coorg in the Western Ghats to the river mouth at the Bay of Bengal (Dekov et al., 1998). Before emptying, it divides into a large number of distributaries forming a wide delta. The river and its main tributaries Hemavati, Kabini, Bhavani and Amaravati drain a wide variety of Precambrian rocks schists, shales, gneisses, granito - gneisses and Quaternary sediments (Wadia, 1975). The climate over the Cauvery basin is tropical. The volume of this rain-fed river fluctuates seasonally. The Cauvery is one of the most utilised rivers in India and it is considerably important for its irrigation (Dekov et al., 1998).

**River basin as an ecosystem**

Ecosystem services refer to the benefits that people attain from ecosystems (Alcamo, 2003; Grizzetti et al.,2016) and the direct and indirect contributions of ecosystems to human well-being (Kumar, 2012). Eco- system services are natural assets produced by the environment and utilized by humans (Maltby and Acreman, 2011). They contribute to social and cultural well-being (Fisher et al., 2009) and have high economic value ((Barbier et al., 1997; Georgiou and Turner, 2012). The basic concept of ecosystem services is connecting people to the nature. Ecosystem services demonstrate the key role of ecosystem functioning and biodiversity to support numerous benefits to humans. Understanding the linkages between natural and socioeconomic systems can lead to improved and more sustainable management of ecosystems (Guerry et al., 2015). Generally, river basins provide a wide range of ecosystem services that are the source of various economic benefits, including products such as timber, medicinal plants and fuelwood, and provide wildlife habitats and spawning grounds (Groot et al., 2002; Knüppe and Knieper, 2016; Rouquette et al., 2011; Sarukhan et al., 2005).Moreover, rivers are considered to be one of the most important pathways for material cycling and provide a wide range of services and functions, such as conservation of biological diversity, flood management, and regulation of climate. Sustainable human development largely depends on the availability of fresh water resources (Zhao et al., 2015). Considering the fact that 98 percent of rainfall passes over or through land on its way to the river (Newson, 1998), rivers and river basins are important components for water resource obtaining and protection.

In river basin systems, social and biophysical elements are all connected, directly or indirectly, through water availability and decisions on its uses (Arnell NW, 2004). Water plays a critical role in maintaining functioning of the ecosystem where a multitude of services are derived (Zhao et al., 2018). Governance of river basins is complex and context specific (Jaspers et al., 2004), nevertheless, many governance issues are similar around the world: drought (demand exceeds supply), flooding (supply exceeds demand) and water quality degradation (pollution, saltwater intrusion, turbidity, algal blooms, etc.) (Molle et al., 2009). Emerging threats to sustainable development of our water resources include changes in hydrology, geomorphology, erosion, sedimentation, and connectivity driven by population pressure, economic development and climate change, and the resulting degradation of freshwater ecosystems and ecosystem services (Alexandra, 2017; Groot et al., 2012). Water crises are evident everywhere, with almost no river basin currently managed sustainably anywhere in the world — a fact which is increasingly recognised as being a failure in governance (Pahl-Wostl, 2009). The crisis of river basin governance has been investigated from the perspectives of collaborative governance (Ansell et al., 2008; Benson et al., 2013) (adaptive governance (Ison et al., 2013; Folke., 2005) and social learning (Pahl-Wostl, 2009), social contracts (covenant action (Hooper, 2008), ecosystem asset management (Chesson, 2013), partnership accountability Hearne, 2017) and top down regulation (hydrocracy and overallocation (Molle et al., 2009), hierarchy theory (McLoughlin et al., 2015), politics of knowledge (Molle, 2008).

Water governance — as manifest through human intervention — aims at changing water cycles for societal or environmental purposes (Bouckaert et al., 2018). The basin biophysical capacity represents water and its ecosystem services delivered naturally or through human actions. The biophysical system consists of three nested spatial scales: local or reach (micro), catchment (meso) and basin (macro) scale (Bouckaert et al., 2018). Specifically, the way we conceptualise landscape and its use in policy implementation will have a direct mediating effect on the biophysical system, as is evidenced in decisions around maintaining riverbank vegetation and wetland connections, water diversions, dam building and river flow regulation (Ison, 2017). These pressures will result in co-evolutionary biophysical adaptations which are not always predictable, but which will impose further constraints on social-institutional evolutionary responses.

Limited availability of fresh water jeopardizes human well-being, hampers economic growth, and contributes to losses of ecosystem functions and biodiversities (Launiainen et al., 2014). Currently, one- third of the world population are facing water scarcity (Manzardo et al., 2014). According to the UNEP (2008), the turning point will arrive in 2025 when almost half of the world’s population would be living in declining situations of water stress due to increased water use (Sultana et al., 2014). One of the prominent problems of water scarcity in some areas is the severe discrepancy of the spatial distribution among the water resources, population and the economic development (Zhang and Anadon, 2014). The spatial imbalance and mismatch of the water endowments and demands have led to significant adverse ecological impacts, posing an immense challenge for the sustainable development of cities and river basins in arid regions (Foster et al., 2004). The increasing pressures on water resources have created the need for critical techniques and strategies related to sustainable water use and management (Sultana et al., 2014). Water resources management at river basins faces the challenges of unbalanced water distributions among different regions and economic sectors. The involvement of multiple regional jurisdictions further complicates the optimal allocation and sustainable management of water resources at river basins (Li et al., 2018).

The water cycle, being the most active phenomenon in biogeochemical cycling, significantly influences the structure and function of basin ecosystems. The judicious allocation and real-time dispatch of water resources are important for basin management (Cai et al., 2010). Vegetation is an indispensable part of basin ecosystem. Its ecological functions are to preserve water and soil and conserve moisture, which play an important role in the protection of basin ecology. One hectare of forest can produce approximately 20% more moisture through evapotranspiration than the same area of arable land (Wang, 2001). Therefore, meeting the ecological water requirement (EWR) to ensure the normal growth of vegetation is an effective guarantee for the stability of ecosystem, the judicious allocation of water resources, and the coordinated development of the ecological and economic water requirements of a basin (Chi et al., 2018). Water scarcity and degradation of water quality in river basins are among the major issues addressed by water resources management authorities. Moreover, two typical challenges associated with water resources management include naturally unbalanced distribution and administrative disparities under multiple jurisdictions at the watershed scale. Effective accounting and management methods are thus desired to deal with such challenges (Li et al., 2018).

**Biodiversity**

Ecosystem services and biodiversity are conceptually debated. Some scholars define biodiversity as the capital generating ecosystem services, others consider biodiversity a service in its own right (Costanza et al., 2014). In its broadest definition, it includes supporting, regulating, provisioning and cultural services (Groot et al., 2012). Decisions about farming practices may influence not only water quantity and quality status, but also other environmental components in a catchment, as well as societies and the economy (Psomas et al., 2016). Designing and implementing measures for sustainable management of water resources in agriculture requires an integrated approach addressing the water-energy-land-food nexus (Hoff, 2011; Dodds et al., 2014) and also taking into account rural development, economic growth and social cohesion. The hydrological processes in a river basin strongly control the spatiotemporal distribution of water resources (i.e., surface and groundwater) and consequently potential water resource related developments in the basin (Kabite et al., 2018).

**River basin sustainability**

Sustainability of a river basin depends on many inter-related factors (Srinivas et al., 2018). Some of these fundamental factors are river water, discharge, sediments and bio-diversity (Arthington et al., 2010; Liu et al., 2017). An integrated study of these factors is essential for developing suitable policies. However, there is a general lack of awareness even amongst the experts to assess the impact of any development project on these essential factors of the river (Srinivas et al., 2018). As a result, river ecosystem gets imbalanced with time, giving rise to numerous problems such as water scarcity, reduced self-purifying capacity, flood risks, loss of delta formation, toxicity, and extinction of aquatics. Meeting such challenges, needs a suitable combination of good governance, local general mass and expert stakeholders, who can effectively manage the long-term, uncertain, and imperfectly known risks related to sustainability of a river basin (Srinivas et al., 2018).

Unfortunately, human activities threaten river networks and cause multiple pressures, affecting the biodiversity and physical status of rivers that result in decreases in the economic value of a river ecosystem (Grizzetti et al., 2016). Globally, most of the rivers in the biosphere have been altered or nearly destroyed due to human activities and destruction (Mauerhofer et al., 2018; Yuan et al., 2005), which is now a major issue and has become a focus of attention (Allan et al., 1997; Hong et al., 2009; Karr, 1991). Human activities such as industry, farm- land irrigation, and residential development have disturbed river eco- systems, water quality, fish passage, bank stability and riparian zones of rivers. The overexploitation of river ecosystem services has created pressures for ecosystems (Grizzetti et al., 2016).

River networks and their services have suffered extensive destruction due to urbanization and industrialization (Khan et al., 2019). In many developing countries such as India and China, water bodies are heavily polluted and availability of freshwater resources is becoming limited (Goonetilleke and Vithanage, 2017). WRG (2009) estimated 40% shortage of freshwater by the year 2030. Over abstraction of river water resources and heavy pollution caused from industrial and domestic sources, solid wastes, and agricultural runoffs will be significantly affecting 15% of the global population (Ligtvoet et al., 2014). Although, it is evident that there is a need to strike a balance between so-called developmental activities and sustainability, still most of the river basins are under constant threat due to mismanaged government bodies, inadequate knowledge about the fundamentals of the riverine ecosystems and its dynamics, poorly implemented policies, and lack of in-depth planning (Mencio et al., 2010).

Sustainable river basin planning and management is a complex and uncertain phenomenon involving social, economic, environmental and several technical criteria (Srinivas et al., 2018). Despite global advancement, the problems associated sustainability have not been sufficiently addressed, due to mismanaged governance, poorly implemented policies, lack of suitable data and over-exploitation of river resources (Srinivas et al., 2018). Therefore, major rivers basins across the globe need an integrative and comprehensive strategic approach considering the diverse stakeholder’s perspective and conflicting criteria pertaining to sustainable management (Srinivas et al., 2018). Over the past three decades, the accelerated industrialization and urbanization across the globe have been posing a huge challenge to the water resource policy makers to formulate strategies, which ensure sustainable development of water resources (Koop et al., 2017).

The complexity of identifying and achieving sustainability requires high degrees of stakeholder trust and participation (Hurlbert and Gupta, 2015). Therefore, a key aspect of sustainable watershed management is stakeholder involvement across multiple levels of governance, including meaningful public involvement (Arnstein, 1969; Shepherd and Bowler, 1997; Leach, 2006; Putnam, 1995b). Healthy watersheds depend on sustainable management practices, which are in turn dependent on levels of public concern to support implementation of these practices (Pretty and Ward, 2001; Axon, 2016). It has become standard practice to refer to any management of rivers and their basins as ‘‘integrated’’. The development and use of the concept reflects a growing appreciation of the complexity of river basins as hydrological, ecological, economic, political and social systems (Campbell et al., 2016). Magnified by multiple factors, including climate change and intensive human intervention, the river basin management strategies cannot meet the needs of the dramatic socioeconomic development, and integrated river basin management strategies are urgently needed in some developing countries and regions (Zhao et al., 2015).

Moreover, there are multiple decision makers with contrasting interests and objectives, and thus, the strategic policies should reflect the viewpoint of all the stakeholders towards the perspective of sustainability and development. Since there are several factors associated with uncertainty and conflicts amongst stakeholders, there is no single best solution to address the issues related to river basin (Srinivas et al., 2018). An integrative approach, which provides all possible alternative solutions along with their relevance is needed (Patterson et al., 2013). The approach should be flexible enough to adapt to the changing environment, which helps in designing the proposed strategies reflecting the individual participation from the bottommost level of regional stake- holders (Bryan et al., 2010). Sustainable river basin management problems are often subjected to uncertainties caused due to randomness and imprecision (Rehana and Mujumdar, 2009; Srinivas and Singh, 2018). Randomness is mainly caused by the random nature of data, such as water quality, stream flow, and other environmental data. The uncertainty due to imprecision is induced by the conflicting judgements of various stakeholders towards the criteria and strategic alternatives.

Conflicts between increasing ecosystem services (ESs) demand and limited or even decreased natural capital hinders the sustainable development of river basins worldwide. The main reason for the conflicts is that human interventions have seriously decoupled the original harmonious relationship between humans and nature (2018). Ongoing population growth and economic development require river basin ecosystems to provide more food, energy and other services to humans (Fu et al., 2015). Climate change further complicates the challenge by altering spatial patterns and size of ecosystem services (Nelson et al., 2013). The reductionism dominated research on river basin management (Cheng et al., 2014; Sendzimir et al., 2007) tends to neglect or simplify these relationships and often leads to unintended consequences. A river basin is a semi-closed ecological and economic system, representing logical management units of the water cycle, throughout which all decisions and actions have interdependent ecological, social and economic implications (Zhao et al., 2018). The Cauvery River is one of the major rivers of the Peninsular India that flows across three states and drain into the Bay of Bengal (Dhanakumar et al., 2015). The river, on its course, receives a considerable amount of industrial effluents, untreated municipal sewage, urban runoff and agricultural runoff (Ramanathan et al., 1993; Jameel and Hussain, 2005; Solaraj et al., 2010).

**Sediments**

The sediment transported by rivers is an integral component of the erosion and denudation of the land surface of the earth by fluvial processes and the associated land-ocean transfer of material plays a key role in global geochemical cycling (Liu et al., 2018). These essentially natural processes have been greatly impacted by anthropogenic activity, resulting, for example, in accelerated erosion caused by changing land use and interruption of land-ocean transfer by storage of large quantities of sediment behind dams (Liu et al., 2018). The transport of sediment through a river system plays an important role in maintaining fluvial environments such as channel systems, floodplains, wetlands, estuaries and deltas. In a natural, undisturbed river basin there is usually equilibrium between erosion and deposition. Under such conditions, rates of soil erosion are generally balanced by rates of soil formation. This equilibrium can be disrupted by extreme climatic events and human activities, such as land clearance, which can cause increased inputs of both runoff and sediment to river systems. If the sediment regime of a river system is not managed effectively in a sustainable manner, this can lead to high operational costs and significant adverse impacts on society and the environment (Liu et al., 2018).

In many river basins, issues related to sedimentation are often exacerbated by the influence of reservoirs and hydraulic works. The combination of sediment trapping and flow regulation has dramatic impacts on the ecology, water turbidity, sediment balance, nutrient budgets and morphology of a river basin (Liu et al., 2018). With the introduction of Integrated Water Resources Management (IWRM) concept globally (Biswas, 2008; Chikozho, 2008; Dombrowsky, 2008; McDonnell, 2008), water resources management policies in both developed and developing countries have been geared towards river basin approaches, while positioning the basin as the envisioned scale for integrated water resources planning, development, and management (Merrey, 2008; Molle, 2008). Supported both discursively and financially by major international donors such as the World Bank (WB) and the Asian Development Bank (ADB) as well as international organizations such as the Global Water Partnership, river basin approaches have become the dominant flagship and mainstream approach of global water programs (Butterworth et al., 2010; UNEP, 2012; UN-Water, 2008; van der Zaag, 2005).

**Heavy Metals**

Among the persistent environmental pollutants, heavy metals are significant due to their ubiquitous presence and nondegradable nature (Dhanakumar et al., 2015). Heavy metal enrichment in the environment occurs through a number of sources including acid mine drainage, industrial emissions, traffic, domestic sewage, storm water, atmo- spheric deposition and building materials (Xia et al., 2011;Wei and Yang, 2010). In developing countries, rapid increase in domestic, agricultural and industrial activities contribute to elevated levels of metals in the air, water and soil (Sharma et al., 2007; Rahman et al., 2010; Solaraj et al., 2010). Aquatic systems including rivers and inland wetlands are among the most affected systems by metal contamination. Therefore, understanding heavy metal pol- lution and its toxicity is a topic of interest in many Asian regions (Sankar et al., 2006; Fu et al., 2013; Taweel et al., 2013; Leung et al., 2014). Several studies have reported on metal concentrations in the water, sediments and the toxicity risk in aquatic organisms (Yi et al., 2011; Kalantzi et al., 2013; Kwok et al., 2014).

Sustainable river basin management problems are often subjected to uncertainties caused due to randomness and imprecision (Rehana and Mujumdar, 2009; Srinivas and Singh, 2018). Randomness is mainly caused by the random nature of data, such as water quality, stream flow, and other environmental data. The uncertainty due to imprecision is induced by the conflicting judgements of various stakeholders towards the criteria and strategic alternatives. Recently, fuzzy based MCGDM techniques have emerged as one of the best approaches to deal with the uncertainties (Singh et al., 2007, 2015; Pan et al., 2017; Srinivas and Singh, 2017). Fuzzy logic plays an emphatic role in framing IRBPM policies by classifying and quantifying the uncertainties using membership functions defined over appropriate fuzzy scale (Singh et al., 2017; Srinivas et al., 2017). Fuzzy Analytical Hierarchy Process (FAHP) has been intensively applied to formulate strategies focused on environmental conservation and water resource management such as flood risk assessment (Zou et al., 2013), geological environmental impact assessment, and pollution assessment of ground- water resources (Azarnivand et al., 2015). Also, open defecation and inorganic farming practices leads to non-point source pollution (Srinivas and Singh, 2018).

**Future Direction**

Using scientific studies for decision making on river basin management is important (Zhao et al., 2015). Increasing concerns about the river health and adverse impacts on river conditions have made it crucial to restore and/or protect current river ecosystems. Restoring ecological conditions at the river level can mitigate human pressures on natural ecosystem of the rivers and pro- mote a healthy ecological environment (Boekhorst et al., 2010; Song et al., 2010). It is broadly acknowledged that it is necessary to expand restoration and management of river attributes from basic water quality improvements to restoration and functioning of ecological systems (Bash and Ryan, 2002; Che et al., 2012a). In terms of ecological goals, the implementation of certain restoration policies is projected to provide considerable environmental benefits (Bateman et al., 2007; Brouwer, 2008).

In order to safeguard the quantity and quality of water resources for future generations, it is necessary to study and measure how the current use of water resources can affect their availability in the future (Pellicer et al., 2016). Water has a central role in sustainable development. Essential for human survival and economic activity, it is also under increasing pressure, with urgent implications for food security and human well-being (Falkenmark et al., 2009; Bigas, 2012; UN-Water, 2013). A putative SDG dedicated to water-related issues aspires to worldwide implementation of Integrated Water Resource Management (IWRM) by 2030.3 IWRM, the coordination of all water related decision making across a drainage basin, is supported and promoted by many international agencies, think tanks, consultancies and academia (Global Water Partnership, 2009; Molle, 2009; Mukhtarov, 2008; Sanchez and Eds, 2014; Snellen and Schrevel, 2004). All versions share the conviction that only a holistic, integrated approach to water management will reduce catastrophic water crises and events in the future. However, integrating policies across political boundaries is difficult (Irvine et al., 2016).

In reality, coordinating policies across basins confronts water managers, policy-makers and societies with highly complex questions (Irvine et al., 2016). Typically, policies are designed for different scales (Young, 2002; Cash et al., 2006), different environmental spheres, and diverse forms of human activities (Pahl-Wostl, 2007; Oberthür and Stokke, 2011). Because long delays occur between policy adoption and visible – positive or negative – impacts on hydrological and natural systems, water governance requires both strong political will and policy-makers capable of grasping long term impacts of policy decisions or environmental changes. Increasing variability in water flows and weather caused by climate change adds the need for a transition to 'adaptive' policies that change whenever natural, social or technical changes render achievement of current objectives impossible (Jeuken and Reeder, 2001; Pahl-Wostl, 2007; Pahl-Wostl et al., 2010a). At the same time, rapid advances in digital technologies dramatically increase the demand for ‘big data’-evidence that supports management (Desouza and Lin, 2011; United Nations, 2014), while simultaneously requiring its validation and legitimacy through public participation and transboundary scientific collaboration (Mason, 2010; UNECE, 2013). Rivers provide humans with vital ecosystem services (Euler et al., 2018). An assessment of river system benefits and recognition of public preferences are crucial for sustainable river management and effective river system restoration (Khan et al., 2019).

An assessment of the impacts of land degradation as a result of anthropogenic land cover alteration on hydrology is crucial for sustainable river basin development and management (Ahiablame and Shakya, 2016). Land degradation, the gradual process of decline in forest biomass, species composition, and soil quality, alters the process of conversion of rainfall to runoff by modifying key hydrological components i.e. evapotranspiration, water yield, infiltration and surface runoff (Costa et al., 2003; Luo et al., 2016; Orewole et al., 2016; Ott and Uhlenbrook, 2004) within a river basin. However, as a result of the complex and dynamic interactions occurring between land cover alterations, climatic variables, and hydrological processes in a river basin, a more intimidating problem of quantifying these changes is presented (Yatheendradas et al., 2008).

These days, Integrated river basin planning and management (IRBPM) is found to be an effective approach as it involves comprehensive viewpoints of multifaceted decision makers (Karamouz et al., 2009; Srinivas et al., 2017). However, successful implementation of IRBPM needs stakeholder involvement along with proper consideration of all social indicators such as ethical and cultural norms, and institutional attitude towards sustainability (Belay et al., 2010). The process develops a systematic plan for a river basin, while considering socio- economic, ecological and environmental criteria. It is also important to develop a suitable mathematical model, which can evaluate the performance of these criteria by incorporating the experience, knowledge and perception of inter-disciplinary experts, having conflicting judgements. Therefore, a multi-criteria group decision making (MCGDM) framework is needed to implement IRBPM, where strategists/stake- holders define realistic alternatives, possibility of outcomes, risk of data error and conflicts in stakeholder’s criteria (Mergias et al., 2007; Garfi et al., 2011).

Contemporarily, aside from agriculture and transportation, humans need more fresh water in the process of industrialization, urbanization and ecological conservation. Integrated river management involves balancing sets of economic, environmental and other interests. Positive trends include the incorporation of all the component of the watershed and taking the basin as a whole unit is fundamentally critical for integrated river management. Furthermore, there is a requirement for improving water governance and long-term planning, and developing strong communication channels between organizations, local communities, and NGO (Zhao et al., 2015). Also, river basin management institutions and scientific river basin study should closely work together for integrated river basin management and development (Zhao et al., 2015). River basin management is a continuous process which involves decisions making and scientific study with the aim of achieving particular goals at some time in the future. Also, the water agreements, laws, institutions, organizations, and scientific projects in the past century have all being improved and modified as time moves on to meet with different situations (Zhao et al., 2015).

**Indicators**

**River basin sustainability indicators from literature review**

|  |  |  |
| --- | --- | --- |
| **Indicator** | **Factors/variables** | **References** |
| River features | Area (A) in km2 | Kabite et al., 2018; Mumtas et al., 2013; Khan et al., 2019; Mehri et al., 2018 |
| Perimeter (P) in km |
| Drainage density (Dd) in km/km2 |
| Stream frequency (Fs) in km-2 |
| Socio-Economic | Poverty |
| Average income |
| migration |
| Productivity | Soil fertility level |
| Yield trends |
| Adoption of new technologies |
| Level of input |
| Risk and Security | Level of soil erosion |
| Drought/flooding frequency |
| Income from livestock |
| Degradation risks/trends |
| Validity | Net and off-farm income |
| Availability of labour |
| Extent of value added |
| Size of land holding |
| Government programs |
| Social acceptability | Personal and family health |
| Off-farm impacts |
| Viability of farming |
| Water quantity | Water flow |
| Ground water recharge |
| E-flow |
| Water quality | Sediments |
| Pesticides |
| Macronutrients |
| Biological elements | Fish biomass |
| Macro invertebrates |
| Hydro morphological structure | Natural habitat |
| Riparian areas |
| Nursery habitat |
| River ecosystem services | Non-drinking water provision (e.g. agriculture, industry, environmental flow, etc.) |
| Water provisioning for drinking |
| Fisheries (food provisioning) |
| Water purification |
| Flood protection |
| Erosion prevention |
| Maintaining nursery population |
| Recreational activities (fishing, swimming, nature viewing, etc.) |
| Temperature |
| Rainfall |
| Humidity |
| Sunny hours during the year |
| Well |
| Land use |
| Foothills and mountains |
| Ground water quality |
| Ground water depth |
| Residential areas |
| Roads |
| Industrial area |
| Fire risk |
| Flood potential |
| Hydrocarbonic soil pollution |
| Landslide Susceptibility |
| Demography | Sex |
| Age |
| Family size |
| Kids under 18 years |
| income |
| Education |

**River basin sustainability indicators by us**

**Outcomes:**

1. Livelihood security and good life
2. Environment quality – river basin sustainability

|  |  |
| --- | --- |
| **Factors** | **Variables** |
| Ecosystem | Annual food grain production |
| Area of irrigated land |
| Tree plantation in homestead land |
| Total forest area / cover (region wise) |
| Average time spent in collecting fuel wood per home hold per week |
| Average time spent collecting water per household per week |
| Average travel time to market |
| Average number of livestock |
| Annual vegetable production |
| Collective selling of agriculture products |
| Tourism visit |
| Encroachment |
| Illicit felling |
| Ability to cope with natural calamity |
| Entertainment/extra-curricular activities (off farm) |
| Capita from forestry works |
| Social Environment | Population |
| Number of homes (pucca) |
| Number of homes with electric service |
| Number of motor cycle |
| Number of mobile phones |
| Infant mortality |
| Number of death due to lack of treatment |
| Percentage of school age children |
| Average age of school leaving |
| Number of people work outside village on daily |
| Number of people migrate from village |
| Number of deaths due to wild animals |
| Number of sanitary latrine per capita |
| Public transport availability |
| Water ways communication |
| Wages |
| Labour migration (inward/outward) |
| Percentage of adult population participating in forest protection committee (FPC) |
| Percentage of women in FPC |
| Percentage of SC/ST and backward population in FPC / village |
| Social unrest |
| Alcoholism |
| Micro credit / SHGs in village |
| Financial status of people around river |
| Banks / financial institution |
| Water Management | Rainfall |
| River flow quantity (TMC) |
| Surface temperature |
| River temperature |
| Nitrate content in river |
| Stress (input vs output) |
| River quality (pollution, flow, heavy metals like zinc, lead etc) |
| PH of river water (acidic and basic) |
| Solids (suspended and dissolved) (plastic & metal) |
| Nitrate content in water |

**Data Analysis**

Around 9 villages are visited which are alongside of the Cauvery river and tributaries, mountains and flood affected regions. The villages are Cherangala, Korangala, Ayangeri, Tantipala, Madenadu, Bettatur, Donikadu, Mandal, Boothana kadu, Makandur. Around 150 responses are collected from the residents of village about their livelihood, dependency on river water, agricultural activities, crops grown and fish biomass.

The average age of the respondents is 52.97 years and family size of the households is 4.23. The expected average family income per annum for the present year is INR 113350 and average family income per annum in the previous year is INR 219390. The expected average agricultural income per annum for the present year is INR 41520, average agricultural income per annum for the last year is INR 127445 and average agricultural income per annum in the last two years is INR 123125. The average land holding is 316.72 cent, average irrigated dry land is 157.52 cent and irrigated wet land is 52.7 cent. The expected average rice grown this year is 14.02 batti (1 batti = 45 kgs) and average rice grown in the last year is 84.90 batti. The expected average coffee grown this year is 13.54 bags (1 bag = 50 kgs) and average coffee grown in the last year is 37.91 bag. The expected average black pepper grown this year is 34.12 kgs and average pepper grown in the last year is 113.63 kgs. The expected average cardamom grown this year (2018) is 1.79 kgs and average cardamom grown in the last year (2017) is 3.91 kgs. The expected average banana grown this year is 14.26 kgs and average banana grown in the last year is 60.70 kgs. The expected average arecanut grown this year is 0.847 kgs and average arecanut grown in the last year is 9.16 kgs. The expected average other crops grown this year (2018) is 2.4 kgs and average other crops grown in the last year (2017) is 31.13 kgs.

**Descriptive Statistics**

|  |  |  |  |
| --- | --- | --- | --- |
| **Variables** | **N** | **Mean** | **Std. Deviation** |
| Age | 150 | 52.97 | 13.996 |
| Family size | 150 | 4.23 | 1.918 |
| Income present | 150 | 113350.667 | 160839.5293 |
| Income last | 150 | 219390.667 | 310960.9323 |
| Agri income present | 150 | 41520.000 | 87676.7415 |
| Agri income last | 150 | 127445.333 | 280824.2577 |
| Agri income last2 | 150 | 123125.333 | 264027.3194 |
| Land holding | 150 | 316.7217 | 413.23433 |
| Irrigated dry | 150 | 157.527 | 855.2334 |
| Irrigated wet | 150 | 52.700 | 101.2035 |
| Rice 18 | 150 | 14.0215 | 73.57167 |
| Coffee 18 | 150 | 13.5445 | 35.96961 |
| Pepper 18 | 150 | 34.120 | 112.8421 |
| Cardamom 18 | 150 | 1.790 | 5.9022 |
| Banana 18 | 150 | 14.267 | 163.4459 |
| Arecanut 18 | 150 | .847 | 7.3373 |
| Others 18 | 150 | 2.400 | 13.9356 |
| Rice 17 | 150 | 84.9031 | 818.51162 |
| Coffee 17 | 150 | 37.9153 | 79.11017 |
| Pepper 17 | 150 | 113.633 | 261.1706 |
| Cardamom 17 | 150 | 3.910 | 12.4779 |
| Banana 17 | 150 | 60.707 | 555.3810 |
| Arecanut 17 | 150 | 9.167 | 45.7864 |
| Others 17 | 150 | 31.133 | 158.5231 |
| Bathing | 150 | 12.013 | 7.4257 |
| Cooking | 150 | 7.013 | 6.6776 |
| Washing | 150 | 19.000 | 13.7377 |
| Watering Plants | 150 | 10.307 | 28.6455 |
| Rearing Animals | 150 | 2.160 | 8.6312 |
| Well Borewell | 150 | 2.993 | 20.6614 |
| Groundwater last5 | 150 | 66.700 | 58.6067 |
| Groundwater last10 | 150 | 61.353 | 53.4030 |
| Fish present | 150 | 1.18 | 2.803 |
| Fish last5 | 150 | 5.270 | 10.8561 |
| River Distance | 150 | 1160.7979 | 1540.91070 |

The average number of pots of water used for bathing in household is 12.01, average number of pots of water used for cooking in household is 7.01, average number of pots of water used for washing in household is 19, average number of pots of water used for watering plants in household is 10.30 and average number of pots of water used for rearing animals in household is 2.16. The average number of well or borewell at households is 2.99. The average ground water depth in last five years is 66.70 feet and average ground water depth in last ten years is 61.35 feet. The average fish biomass in the present year (2018) is 1.18 kgs and average fish biomass in the last five years is 5.27 kgs. The average distance between the farming land and the river is 1160 metres.

From the figure 1 it is evident that the expected family income (2018) of most of the households is less than INR 300000 whereas the family income in 2017 of most of the households is better than the present year.

Figure 1: Family Income

Only few households have family income in 2017 more than INR 500000 and even their income is drastically reduced below INR 500000. This is because of heavy rainfall in 2018 which has caused the reduction in agricultural produce to larger extent.

Figure 2: Agricultural Income

From the figure 2 it is evident that the expected agricultural income (2018) of most of the households is less than INR 300000 whereas the agricultural income in 2017 and 2016 of most of the households is better than the present year. Only few households have family income in 2017 and 2016 more than INR 500000 and even their income is drastically reduced below INR 500000. This is because of heavy rainfall in 2018 which has caused the reduction in agricultural produce to larger extent.

Figure 3: River Distance

From the figure 3 it is evident that, distance between good number of farming land and Cauvery river and its tributaries is less than a kilometre. Similarly, some of the farming lands distance between river is two kilometre and above.

Figure 4: Fish Biomass

From the figure 4 it is evident that, presently the fish biomass in the river is around one kg whereas five years before, fish biomass was more than 20 kg in the river. According to the local people, this drastic reduction of fish biomass is due to the use of fertilizers, pesticides, mud sediments in the river, plastic and cloth wastes, blasting dynamites in the river for fishing.

Figure 5: Fish Biomass

From the figure 5 it is evident that, the ground water depth in the last five years is between 50 to 150 feet in most of the villages. Whereas the ground water depth in the last ten years is little less than the last five years but not drastic change.

Figure 6: Adequate Rainfall

From the figure 6 it is evident that the most of the respondents responded that, in the present year (2018) the rainfall is more whereas in the previous year (2017), most of the respondents responded that there was an adequate rainfall.

Figure 7: Domestic Water Use

From the figure 7 it is evident that in the domestic water use, 10 to 20 pots were used for bathing, 10 to 20 pots for cooking and 20 to 40 pots for washing.

Figure 8: Non-Domestic Water Use

From the figure 8 it is evident that in the non-domestic water use, around 5 to 10 pots were used for watering plants and 10 to 20 pots for rearing animals.

Figure 9: Land holding

From the figure 9 it is evident that, most of the households have 200 to 500 cent of land holdings. Also, good number of households have less than 10 cent of land holdings. Only few households have more than 1000 cent of land holdings.

Figure 10: Irrigated Land

From the figure 10 it is evident that, most of the dry and wet lands are not irrigated. Only few households have dry and wet lands irrigated and they range between 200 to 1700 cent dry land and 500 cent of wet land.

**Cluster Analysis**

For clustering the homogenous groups of respondents, two-step clustering method is employed in this study. From the analysis, three clusters emerged consisting of 64, 60 and 26 respondents respectively. Cluster 1 is named as low income cluster having small land holding, cluster 2 is named as medium income cluster having medium land holding and high income cluster having large land holding. Low income cluster has the average land holding is 88.99 cent, the expected average agricultural income for the present year (2018) is INR 5,716 and agricultural income for the previous year (2017) is INR 16,216. Medium income cluster has the average land holding is 292.73 cent, the expected average agricultural income for the present year (2018) is INR 35,937 and average agricultural income for the previous year (2017) is INR 87,559. High income cluster has the average land holding is 901.31 cent, the expected average agricultural income for the present year (2018) INR 1,37,884 and average agricultural income for the previous year (2017) INR 457,384. Around 10 villages comes under low income cluster, 3 villages under medium income cluster and 4 villages under high income cluster. In the low income cluster, the ground water depth in last 10 years is 99.60 feet and last 5 years is 108.35 feet. In the medium income cluster, the ground water depth in last 10 years is 33.84 feet and last 5 years is 37.17 feet. In the high income cluster, the ground water depth in last 10 years is 40.81 and last 5 years is 43.27.

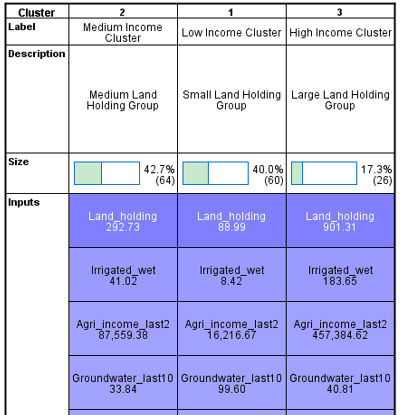
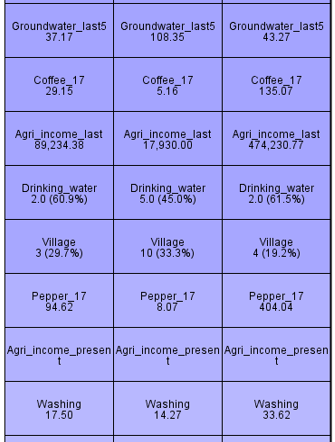
 

Figure 11a & 11b: Clusters

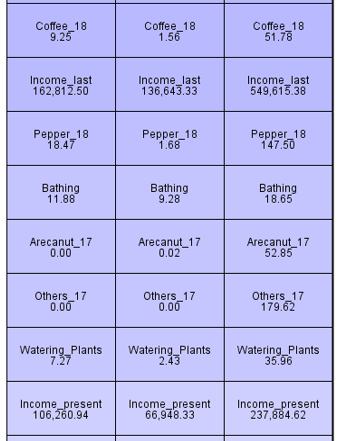
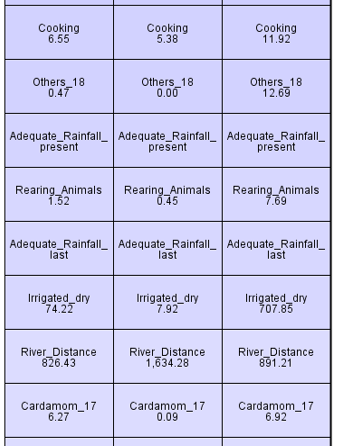
 

Figure 11c & 11d: Clusters

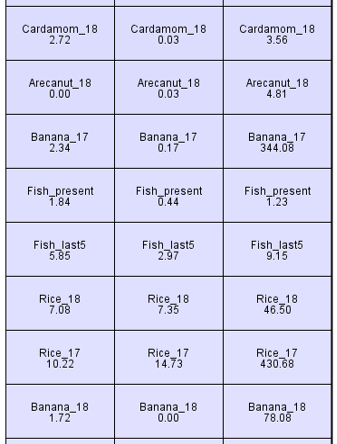
 

Figure 11e & 11f: Clusters

**Questionnaire on Sustainability of Cauvery River Basin, Kodagu, Karnataka**

1. Age (respondent): \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

2. Gender: Male Female

3. Qualification: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

4. Family size (currently staying in the house hold): \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

5. Family income per month.

|  |  |
| --- | --- |
| Current year |  |
| Last year |  |

6. Annual income from farming.

|  |  |
| --- | --- |
| Current year |  |
| Last year |  |
| Last 2 years |  |

7. Size of land holding (kuntes/acre/hectare): \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

8. Area of irrigated land.

|  |  |
| --- | --- |
| Dry land |  |
| Wet land |  |

9. Amount of yields from your land holding.

This year (2017-18)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Land type | Winter (December to March) | Summer (April to June) | Monsoon/Rainy (July to Sept) | Post-monsoon / Autumn (Oct to Nov) |
| Dry Land | Rice\_\_\_\_\_\_\_  Coffee\_\_\_\_\_\_  Black pepper\_\_\_\_\_  Cardamom\_\_\_\_\_\_\_  Orange\_\_\_\_\_\_\_\_\_\_  Vanilla\_\_\_\_\_\_\_\_\_\_  Rubber\_\_\_\_\_\_\_\_\_\_  Teak\_\_\_\_\_\_\_\_\_\_  Cocoa\_\_\_\_\_\_\_\_\_  Banana\_\_\_\_\_\_\_\_  Areca nut\_\_\_\_\_\_\_\_  Vinegar\_\_\_\_\_\_\_\_\_  Spices\_\_\_\_\_\_\_\_\_\_  Butter fruit\_\_\_\_\_\_  Others\_\_\_\_\_\_\_\_\_ | Rice\_\_\_\_\_\_\_  Coffee\_\_\_\_\_\_  Black pepper\_\_\_\_\_  Cardamom\_\_\_\_\_\_\_  Orange\_\_\_\_\_\_\_\_\_\_  Vanilla\_\_\_\_\_\_\_\_\_\_  Rubber\_\_\_\_\_\_\_\_\_\_  Teak\_\_\_\_\_\_\_\_\_\_  Cocoa\_\_\_\_\_\_\_\_\_  Banana\_\_\_\_\_\_\_\_  Areca nut\_\_\_\_\_\_\_\_  Vinegar\_\_\_\_\_\_\_\_\_  Spices\_\_\_\_\_\_\_\_\_\_  Butter fruit\_\_\_\_\_\_  Others\_\_\_\_\_\_\_\_\_\_ | Rice\_\_\_\_\_\_\_  Coffee\_\_\_\_\_\_  Black pepper\_\_\_\_\_  Cardamom\_\_\_\_\_\_\_  Orange\_\_\_\_\_\_\_\_\_\_  Vanilla\_\_\_\_\_\_\_\_\_\_  Rubber\_\_\_\_\_\_\_\_\_\_  Teak\_\_\_\_\_\_\_\_\_\_  Cocoa\_\_\_\_\_\_\_\_\_  Banana\_\_\_\_\_\_\_\_  Areca nut\_\_\_\_\_\_\_\_  Vinegar\_\_\_\_\_\_\_\_\_  Spices\_\_\_\_\_\_\_\_\_\_  Butter fruit\_\_\_\_\_\_  Others\_\_\_\_\_\_\_\_\_ | Rice\_\_\_\_\_\_\_  Coffee\_\_\_\_\_\_  Black pepper\_\_\_\_\_  Cardamom\_\_\_\_\_\_\_  Orange\_\_\_\_\_\_\_\_\_\_  Vanilla\_\_\_\_\_\_\_\_\_\_  Rubber\_\_\_\_\_\_\_\_\_\_  Teak\_\_\_\_\_\_\_\_\_\_  Cocoa\_\_\_\_\_\_\_\_\_  Banana\_\_\_\_\_\_\_\_  Areca nut\_\_\_\_\_\_\_\_  Vinegar\_\_\_\_\_\_\_\_\_  Spices\_\_\_\_\_\_\_\_\_\_  Butter fruit\_\_\_\_\_\_  Others\_\_\_\_\_\_\_\_\_ |
| Wet land | Rice\_\_\_\_\_\_\_\_\_\_  Coffee\_\_\_\_\_\_\_\_  Black pepper\_\_\_\_\_  Cardamom\_\_\_\_\_\_\_  Orange\_\_\_\_\_\_\_\_\_\_  Vanilla\_\_\_\_\_\_\_\_\_\_  Rubber\_\_\_\_\_\_\_\_\_\_  Teak\_\_\_\_\_\_\_\_\_\_  Cocoa\_\_\_\_\_\_\_\_\_  Banana\_\_\_\_\_\_\_\_  Areca nut\_\_\_\_\_\_\_\_  Vinegar\_\_\_\_\_\_\_\_\_  Spices\_\_\_\_\_\_\_\_\_\_  Butter fruit\_\_\_\_\_\_  Others\_\_\_\_\_\_\_\_\_ | Rice\_\_\_\_\_\_\_\_\_  Coffee\_\_\_\_\_\_\_\_  Black pepper\_\_\_\_\_  Cardamom\_\_\_\_\_\_\_  Orange\_\_\_\_\_\_\_\_\_\_  Vanilla\_\_\_\_\_\_\_\_\_\_  Rubber\_\_\_\_\_\_\_\_\_\_  Teak\_\_\_\_\_\_\_\_\_\_  Cocoa\_\_\_\_\_\_\_\_\_  Banana\_\_\_\_\_\_\_\_  Areca nut\_\_\_\_\_\_\_\_  Vinegar\_\_\_\_\_\_\_\_\_  Spices\_\_\_\_\_\_\_\_\_\_  Butter fruit\_\_\_\_\_\_  Others\_\_\_\_\_\_\_\_\_\_ | Rice\_\_\_\_\_\_\_\_\_  Coffee\_\_\_\_\_\_\_\_  Black pepper\_\_\_\_\_  Cardamom\_\_\_\_\_\_\_  Orange\_\_\_\_\_\_\_\_\_\_  Vanilla\_\_\_\_\_\_\_\_\_\_  Rubber\_\_\_\_\_\_\_\_\_\_  Teak\_\_\_\_\_\_\_\_\_\_  Cocoa\_\_\_\_\_\_\_\_\_  Banana\_\_\_\_\_\_\_\_  Areca nut\_\_\_\_\_\_\_\_  Vinegar\_\_\_\_\_\_\_\_\_  Spices\_\_\_\_\_\_\_\_\_\_  Butter fruit\_\_\_\_\_\_  Others\_\_\_\_\_\_\_\_\_ | Rice\_\_\_\_\_\_\_\_\_\_  Coffee\_\_\_\_\_\_\_\_  Black pepper\_\_\_\_\_  Cardamom\_\_\_\_\_\_\_  Orange\_\_\_\_\_\_\_\_\_\_  Vanilla\_\_\_\_\_\_\_\_\_\_  Rubber\_\_\_\_\_\_\_\_\_\_  Teak\_\_\_\_\_\_\_\_\_\_  Cocoa\_\_\_\_\_\_\_\_\_  Banana\_\_\_\_\_\_\_\_  Areca nut\_\_\_\_\_\_\_\_  Vinegar\_\_\_\_\_\_\_\_\_  Spices\_\_\_\_\_\_\_\_\_\_  Butter fruit\_\_\_\_\_\_  Others\_\_\_\_\_\_\_\_\_ |

Last year (2016-2017)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Land type | Winter (December to March) | Summer (April to June) | Monsoon/Rainy (July to Sept) | Post-monsoon / Autumn (Oct to Nov) |
| Dry Land | Rice\_\_\_\_\_\_\_  Coffee\_\_\_\_\_\_  Black pepper\_\_\_\_\_  Cardamom\_\_\_\_\_\_\_  Orange\_\_\_\_\_\_\_\_\_\_  Vanilla\_\_\_\_\_\_\_\_\_\_  Rubber\_\_\_\_\_\_\_\_\_\_  Teak\_\_\_\_\_\_\_\_\_\_  Cocoa\_\_\_\_\_\_\_\_\_  Banana\_\_\_\_\_\_\_\_  Areca nut\_\_\_\_\_\_\_\_  Vinegar\_\_\_\_\_\_\_\_\_  Spices\_\_\_\_\_\_\_\_\_\_  Butter fruit\_\_\_\_\_\_  Others\_\_\_\_\_\_\_\_\_ | Rice\_\_\_\_\_\_\_  Coffee\_\_\_\_\_\_  Black pepper\_\_\_\_\_  Cardamom\_\_\_\_\_\_\_  Orange\_\_\_\_\_\_\_\_\_\_  Vanilla\_\_\_\_\_\_\_\_\_\_  Rubber\_\_\_\_\_\_\_\_\_\_  Teak\_\_\_\_\_\_\_\_\_\_  Cocoa\_\_\_\_\_\_\_\_\_  Banana\_\_\_\_\_\_\_\_  Areca nut\_\_\_\_\_\_\_\_  Vinegar\_\_\_\_\_\_\_\_\_  Spices\_\_\_\_\_\_\_\_\_\_  Butter fruit\_\_\_\_\_\_  Others\_\_\_\_\_\_\_\_\_\_ | Rice\_\_\_\_\_\_\_  Coffee\_\_\_\_\_\_  Black pepper\_\_\_\_\_  Cardamom\_\_\_\_\_\_\_  Orange\_\_\_\_\_\_\_\_\_\_  Vanilla\_\_\_\_\_\_\_\_\_\_  Rubber\_\_\_\_\_\_\_\_\_\_  Teak\_\_\_\_\_\_\_\_\_\_  Cocoa\_\_\_\_\_\_\_\_\_  Banana\_\_\_\_\_\_\_\_  Areca nut\_\_\_\_\_\_\_\_  Vinegar\_\_\_\_\_\_\_\_\_  Spices\_\_\_\_\_\_\_\_\_\_  Butter fruit\_\_\_\_\_\_  Others\_\_\_\_\_\_\_\_\_ | Rice\_\_\_\_\_\_\_  Coffee\_\_\_\_\_\_  Black pepper\_\_\_\_\_  Cardamom\_\_\_\_\_\_\_  Orange\_\_\_\_\_\_\_\_\_\_  Vanilla\_\_\_\_\_\_\_\_\_\_  Rubber\_\_\_\_\_\_\_\_\_\_  Teak\_\_\_\_\_\_\_\_\_\_  Cocoa\_\_\_\_\_\_\_\_\_  Banana\_\_\_\_\_\_\_\_  Areca nut\_\_\_\_\_\_\_\_  Vinegar\_\_\_\_\_\_\_\_\_  Spices\_\_\_\_\_\_\_\_\_\_  Butter fruit\_\_\_\_\_\_  Others\_\_\_\_\_\_\_\_\_ |
| Wet land | Rice\_\_\_\_\_\_\_\_\_\_  Coffee\_\_\_\_\_\_\_\_  Black pepper\_\_\_\_\_  Cardamom\_\_\_\_\_\_\_  Orange\_\_\_\_\_\_\_\_\_\_  Vanilla\_\_\_\_\_\_\_\_\_\_  Rubber\_\_\_\_\_\_\_\_\_\_  Teak\_\_\_\_\_\_\_\_\_\_  Cocoa\_\_\_\_\_\_\_\_\_  Banana\_\_\_\_\_\_\_\_  Areca nut\_\_\_\_\_\_\_\_  Vinegar\_\_\_\_\_\_\_\_\_  Spices\_\_\_\_\_\_\_\_\_\_  Butter fruit\_\_\_\_\_\_  Others\_\_\_\_\_\_\_\_\_ | Rice\_\_\_\_\_\_\_\_\_  Coffee\_\_\_\_\_\_\_\_  Black pepper\_\_\_\_\_  Cardamom\_\_\_\_\_\_\_  Orange\_\_\_\_\_\_\_\_\_\_  Vanilla\_\_\_\_\_\_\_\_\_\_  Rubber\_\_\_\_\_\_\_\_\_\_  Teak\_\_\_\_\_\_\_\_\_\_  Cocoa\_\_\_\_\_\_\_\_\_  Banana\_\_\_\_\_\_\_\_  Areca nut\_\_\_\_\_\_\_\_  Vinegar\_\_\_\_\_\_\_\_\_  Spices\_\_\_\_\_\_\_\_\_\_  Butter fruit\_\_\_\_\_\_  Others\_\_\_\_\_\_\_\_\_\_ | Rice\_\_\_\_\_\_\_\_\_  Coffee\_\_\_\_\_\_\_\_  Black pepper\_\_\_\_\_  Cardamom\_\_\_\_\_\_\_  Orange\_\_\_\_\_\_\_\_\_\_  Vanilla\_\_\_\_\_\_\_\_\_\_  Rubber\_\_\_\_\_\_\_\_\_\_  Teak\_\_\_\_\_\_\_\_\_\_  Cocoa\_\_\_\_\_\_\_\_\_  Banana\_\_\_\_\_\_\_\_  Areca nut\_\_\_\_\_\_\_\_  Vinegar\_\_\_\_\_\_\_\_\_  Spices\_\_\_\_\_\_\_\_\_\_  Butter fruit\_\_\_\_\_\_  Others\_\_\_\_\_\_\_\_\_ | Rice\_\_\_\_\_\_\_\_\_\_  Coffee\_\_\_\_\_\_\_\_  Black pepper\_\_\_\_\_  Cardamom\_\_\_\_\_\_\_  Orange\_\_\_\_\_\_\_\_\_\_  Vanilla\_\_\_\_\_\_\_\_\_\_  Rubber\_\_\_\_\_\_\_\_\_\_  Teak\_\_\_\_\_\_\_\_\_\_  Cocoa\_\_\_\_\_\_\_\_\_  Banana\_\_\_\_\_\_\_\_  Areca nut\_\_\_\_\_\_\_\_  Vinegar\_\_\_\_\_\_\_\_\_  Spices\_\_\_\_\_\_\_\_\_\_  Butter fruit\_\_\_\_\_\_  Others\_\_\_\_\_\_\_\_\_ |

10. What kind of irrigation methods are used?

|  |  |
| --- | --- |
| Rain-fed farming |  |
| Surface irrigation (Canal) |  |
| Localized irrigation (piped network) |  |
| Drip irrigation |  |
| Sprinkler irrigation |  |
| Manual irrigation |  |
| Pump set |  |
| Others |  |

11. Do you use any pesticides and what quantity?

|  |  |
| --- | --- |
| Insecticides (insects) |  |
| Fungicides (fungi) |  |
| Herbicides (plants) |  |
| Rodenticides (rats and mice) |  |
| Bactericides (bacteria) |  |
| Larvicides (larvae) |  |
|  |  |

12. Do you use any fertilizers and what quantity?

|  |  |
| --- | --- |
| Nitrogenous fertilizer |  |
| Organic Nitrogenous fertilizer |  |
| Phosphate fertilizer |  |
| Potassic fertilizer |  |
| Compound fertilizer |  |
| Complete fertilizer (NPK) |  |
|  |  |

13. Has soil erosion happened and what kind?

|  |  |
| --- | --- |
| Surface erosion |  |
| Fluvial erosion |  |
| Mass-movement erosion |  |
| Streambank erosion |  |
|  |  |

14. What is the drought frequency in every season and how many times?

|  |  |  |  |
| --- | --- | --- | --- |
| Season | Current year | Last year | Last 5 years |
| Winter |  |  |  |
| Summer |  |  |  |
| Monsoon/Rainy |  |  |  |
| Autumn |  |  |  |

15. What is the flooding frequency in every season and how many times?

|  |  |  |  |
| --- | --- | --- | --- |
| Season | Current year | Last year | Last 5 years |
| Winter |  |  |  |
| Summer |  |  |  |
| Monsoon/Rainy |  |  |  |
| Autumn |  |  |  |

16. Amount of water collected for household per day.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Domestic | | | Non-Domestic | | |
| Bathing | Cooking | Washing | Watering plants | Rearing animals | Industry |
| Number of pots |  |  |  |  |  |  |

17. Amount of livestock do you possess.

|  |  |
| --- | --- |
| **Livestock** | **Number** |
| Cattle |  |
| Goat |  |
| Sheep |  |
| Poultry |  |
| Pig |  |
| Others |  |

18. What kind of industries are present in this locality?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

19. Does anyone work outside the village in your family every day (morning to evening)? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

20. How many of them have migrated from village in your family in last 5 years? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

21. What is the inward migration in your area/locality in last 5 years? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

22. Is there an adequate rainfall happening for your crop and plantations/tree?

|  |  |  |
| --- | --- | --- |
|  | Crop | Plantation/trees |
| Present year |  |  |
| Last year |  |  |

23. How is the river quality since last 5 years?

|  |  |
| --- | --- |
| Level of water |  |
| Pollutants |  |
| Heavy metals (zinc, lead etc) |  |
| Sediments |  |
| Others |  |

24. Do you have well/borewell in your farming land/house and how many? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

25. What is the approximate ground water depth?

|  |  |
| --- | --- |
| Last 5 years |  |
| Last 10 years |  |

26. What is the water provisioning for drinking?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

27. Fishing in the river.

|  |  |  |
| --- | --- | --- |
|  | Daily | Weekly |
| Quantity |  |  |
| Fish type |  |  |

28. What is the fish biomass in last 5 years?

|  |  |  |
| --- | --- | --- |
|  | Current year | Last 5 years |
| Quantity |  |  |

29. What is the viability of farming from perspective of water?

|  |  |  |  |
| --- | --- | --- | --- |
| Period | Ease (easy/difficult) | Affordability | Distance |
| Current year |  |  |  |
| Last 2 years |  |  |  |
| Last 5 years |  |  |  |

30. Mechanisms used for water purification.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

31. Mechanisms used for flood protection?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

32. Mechanisms used for soil erosion prevention?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

33. Do you have any nursery activities?

|  |  |  |
| --- | --- | --- |
| Type | Quantity | Income |
| Off farm |  |  |
| Nursery plantation |  |  |
| Dairy farming |  |  |
| Honey keeping |  |  |
| Others |  |  |

34. Any other information would you like to provide/share about river Cauvery?

|  |  |
| --- | --- |
| Good things | Problems |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

35. Any other comments/suggestion?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_