Article

Climate Change-Induced Drought Impacts, Adaptation and Mitigation Measures in Semi-Arid Pastoral and Agricultural Watersheds

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Abstract: Periodic drought is a major challenge in drought-prone areas of South Asia. A sample survey of farmers (n = 400) from South Asia was conducted to study the farmers’ perception about drought impacts on their socio-economic status, agro-biodiversity, and adaptation besides public institutions’ drought mitigation measures. The results revealed reduced surface and groundwater availability, soil degradation, partial or complete crop failure, increased agricultural fallows and wastelands, biodiversity loss, decrease in agricultural yields, pasture lands, and livestock in drought-impacted South Asia. About 16–26% of the farmers perceived a reduction in the agricultural area and production of commercial crops and millets in drought-prone areas, while changes in the cropping of pulses, oilseeds, horticultural, and fodder crops were minimal. About 57–92% of respondents showed a reduction in the consumption of fruits, vegetables, dairy products, and fish. Unemployment, migration, reduced farm income, and malnutrition were major socio-economic impacts among respondents (38–46%). Despite sufficient public support as a mitigation strategy, the farmers had poor participation (8–65%) for agri-information and adaptation (7–36%) against drought impacts. Hence, researchers, extension agents, and policymakers must develop efficient ‘participatory-mode’ drought adaptation and mitigation policies in watershed-based semi-arid pastoral and agricultural regions of South Asia and similar agro-ecologies across the globe.

Keywords: climate change; drought; watersheds; pasture; livestock; socio-economic impact; adaptation

1. Introduction

Climate is a complex system within which the physical climatic changes are driven by the joint effect of economic, environmental and political as well as social forces [1]. The long period of industrialization is responsible for the release of greenhouse gases (GHGs), which have led to an increase in the atmospheric temperature at an average
rate of 0.07 °C per decade since 1880; the average rate has increased twice since 1981 (0.18 °C), accelerating global warming and climate change issues. Climate change issues cause various climate-related hazards, such as floods, droughts, intense summers, extreme heat waves, slight cool weather events, storms and other extreme weather events [2,3]. Among the climate change induced natural hazards, the drought ranks first in terms of the number of people directly being affected largely in Asian, African and Sub-Saharan countries [4,5]. A drought is a period of time during which an area or region lacks adequate precipitation and below-normal precipitation. It causes reduced soil moisture, reduce surface and ground water storages [6,7]. The Indian Meteorological Department (IMD) defines the meteorological drought as a situation where rainfall over an area is less than 75% of the climatological normal [3]. The increasing temperature, water stress, frequency of El-Nino events, and the absence of accessible moisture in the atmosphere cause a decrease in precipitation; hence, all these factors lead to a decrease in the number of rainy days and an increase in droughts, specifically in arid and semi-arid agro-ecologies [8]. These droughts have drastically reduced the agricultural production and pastoral ecosystems’ qualities in the arid and semi-arid regions of Asia, Africa and other continents, particularly in highly populated India and China in Asia. It is reported that reduced and ill-distributed rainfall in the monsoon season causes crop failure in an early-season drought, and yield losses in the mid-season and late-season droughts in the semi-arid regions [9]. At the same time, the South Asian farmers are facing the challenge of achieving ~30% increased food production for the increased population by 2030 that is also under impeding climate change-induced drought threats [6]. The impact of climate change is now well established on living systems and the environment, and thus, on the sustainability of food, nutritional and livelihood security [4,5]; hence, it has emerged as a great challenge to address the United Nation’s Sustainable Development Goals (SDGs). The changing climate impacts are closely linked with water, food supply, health, industry, and ecosystems integrity. It also creates additional burden to poor masses in climate vulnerable regions through the socio-economic issues of malnutrition, inequality, poverty, ecological degradation and other added risks to livelihoods and further discrimination in the future [10].

Among the Asian, African and other continents’ arid and semi-arid developing world, the South Asian agriculture is highly vulnerable to climate change [2]. In South Asia as well as in India, over the last three decades, the drought occurrence has been very common once in every three years’ span. Since the 1990s, India has been experiencing prolonged and widespread droughts in consecutive years and the consequences as well [3,11]. It affects two thirds of the population, depending on the monsoon rainfall-based rainfed agriculture [2]. Hence, the changes in the rainfall patterns have amply affected the Indian agrarian economy, particularly in the southern semi-arid regions. In Southern India, over the centuries, the people have practiced community-based water ponds and tank-fed watershed management practices. Indian government has also implemented several integrated watershed management programs (IWMPs) and people’s participatory watershed development programs (PPWDPs) since the 1970s in several arid and semi-arid regions. The micro-watershed level soil and water conservation and management programs are also being implemented in various arid and semi-arid regions to conserve water and escape droughts [11]. However, at the farm level, most of the farmers do not adopt these soil and water conservation measures as well as other eco-friendly agricultural practices for drought adaptation [11,12]. Hence, it adversely affects the effectiveness of the IWMPs and PPWDPs and, thus, the resultant ecosystem services viz., soil and water conservation, ground water recharge and agro-biodiversity conservation, etc. [11]. The adaptation refers to changes in processes, practices and arrangements to moderate the probable compensations or to benefit from the opportunities associated with climate change impacts [13]. The drought mitigation practices/techniques may help in attaining the ecosystem sustainability during droughts and the drought-related aridity. It allows to cushion the harmful effects of drought on humans, livelihoods, and the environment [14]. The effective drought adaptation and mitigation measures support the adjustments in ecological, social, and economic systems.
in response to actual or expected climatic stimuli and their impacts. Since the semi-arid regions of Southern India are highly vulnerable to climate change-induced droughts [3,6], a research study was conducted in drought-prone semi-arid regions of Southern India as a representative unit for semi-arid South Asia to assess the existing farmers’ perception about drought impacts, adaptation and mitigation measures in the semi-arid pastoral and agricultural watersheds of the region. The outcomes of this study may suggest suitable policy interventions, need-based appropriate people’s participatory schemes/action plan for effective adaptation and mitigation measures in semi-arid pastoral and agricultural watersheds of South Asia and similar semi-arid pastoral and agricultural watersheds across the world.

2. Materials and Methods

2.1. Study Area

Southern India’s agricultural and socio-economic settings act as an appropriate representative unit for the entire South Asian semi-arid regions. Hence, the study area was selected from the semi-arid regions of four states of southern India viz. Tamil Nadu, Kerala, Karnataka and Telangana. Moreover, the study area has wider climatic variabilities, where the mean maximum temperature varies between 29 and 40 °C, the mean minimum temperature varies between 16 and 25 °C and the daily mean temperature varies between 22 and 34 °C. The region receives average annual rainfall of ~600–950 mm; ~80% of which is received in two wet seasons’ viz. south-west and north-east monsoons. Agriculture is the major livelihood activity in all these selected states. Further, the climate change-induced frequent drought implications cause pastoral, agricultural and other livelihood vulnerabilities in these states, though the farmers adopt certain adaptation and mitigation measures. Hence, it is high time to study the farmers’ perception about drought impacts, adaptation and mitigation measures in the watershed-based semi-arid pastoral and agricultural regions of these four states of Southern India. So, the research study was conducted in the four states of Southern India (Figure 1). The selection of the districts in these four states was determined using a stratified random technique with the semi-arid pastoral and agricultural watershed area coverage of 45–90% diversifications. Again, there was a random selection of the watersheds in these selected districts, as they have true representation of semi-arid pastoral and agricultural watersheds in the region. Hence, finally we selected the Kovilpatti watershed (Watershed Code 4A1C5) of the Thoothukudi district, and the Andipatti watershed (Watershed Code 4A2A6) of the Theni district in Tamil Nadu; the Mannarkad watershed (Watershed Code 4B2F4) of the Palakkad district in Kerala; the Tiptur watershed (watershed Code 4D3F3) of the Tumkur district in Karnataka; and the Medchal watershed (Watershed Code 4E5A3) of the Medchal–Malkajgiri district in Telangana state (Figure 1). Tamil Nadu has wider climatic variabilities under a semi-arid agro-ecology; so, two different watersheds were taken for the study in Tamil Nadu state. In these selected semi-arid pastoral and agricultural watersheds, there were different socio-economic centric pastoral and agricultural households comprising landless farmers (19.5–26.4%), dryland farmers (16.4–19.2%), rainfed farmers (28.7–34.4%), less irrigated farmers (18.2–22.6%), medium irrigated farmers (11.2–13.6%) and high (assured) irrigated farmers (4.4–9.2%), mostly belonging to the backward classes and scheduled caste social categories. Hence, the selection of these five semi-arid pastoral and agricultural watersheds of Southern India was highly justified as being representative unit of South Asian agricultural and socio-economic settings. In addition, the frequent drought occurrence, agro-ecological diversification, semi-arid climate and socio-economic variations in these four states truly make them representative units of South Asia.
Against this background, numerous research questions were raised to evaluate the present status of climate change-induced drought impacts in the semi-arid pastoral and agricultural watersheds (Supplementary File S1). For example, what is the present level of adaptation measures taken against drought in the semi-arid pastoral and agricultural watersheds? What are the socio-psycho, socio-economic and non-formal education related variables contributing against the climate change induced drought adaptation process in semi-arid pastoral and agricultural watersheds? Moreover, a hypothesis is a conjectural statement of relation between two or more variables in a declarative sentence form which supports the testing of relationships of climate change-induced drought adaptation measures [15,16]. For the study, the null hypothesis (H₀) states that there is no significant relationship between the socio-economic variables and climate change-induced drought adaptation measures. Likewise, the alternative hypothesis H₁ of the study states that there may be a significant relationship between the socio-economic variables of the farmers and climate change-induced drought adaptation measures. At last, it supports the assessment of the significant variables against the climate-induced drought adaptation process.
2.2. Data Collection and Statistical Analysis

The data were collected by personal interviews using a semi-structured survey schedule (Supplementary File S1). The schedules intended to collect information on farmers’ socio-economic characteristics, perception on climate change (drought) impacts, status on area and production of various crops, perception on various socio-economic impacts, households’ daily food consumption pattern, usage of weather information to agricultural activities, social participation and extension agency contact levels, awareness about the climate change related drought impacts, various adaptation and mitigation measures against the drought impacts, etc. The relevant survey was conducted during the years 2018 and 2019. In addition, we updated the information from the respondent farmers during 2020 and 2021 through telephonic communication using the above survey schedule (Supplementary File S1). The individual farming household was considered a primary sampling unit. A multi-stage random sampling was used to select samples from each district. In each district/watershed, the farmers of different categories viz. landless farmers, dryland farmers, rainfed farmers, less irrigated farmers, medium irrigated farmers and high (assured) irrigated farmers were sampled. These diverse socio-economic centric pastoral and agricultural households were selected randomly using a sample size of 80 from each district for a total sample size of 400 farm households (n = 400). The collected data were coded, processed and classified into tables and analyzed using the statistical package for social sciences (SPSS). Data analysis techniques included basic descriptive statistics (such as frequencies, percentages, and means) and a binary logistic regression analysis model. The binary logistic regression analysis was used to investigate the manipulative power of adoption decision-making processes based on factors that may influence the farmers to adopt climate induced drought adaptation strategies [17]. It helps to find out the contributed socio-psycho, socio-economic and non-formal education related variables against the climate change-induced drought impact adaptation process to make a meaningful inference from the study [12].

3. Results and Discussion

3.1. Socio-Economic Characteristics of the Households

A total of 400 households (n = 400) were interviewed from 5 districts situated in 4 different states of Southern India (Table 1). The average age of the respondents was 46 years (range 26–78 years). Since the old age farmers mostly relied on indigenous knowledge-based drought adaptations strategies while the young farmers with comparatively better educational status mostly trusted on digital platforms for the weather-based information systems, the current study cohesively covered both these information regimes utilized by the farmers in the survey schedule. The mean household size of the sampled population was 4.5. Data on education indicated that 7.3%, 29.5%, 30.2%, 21.2% and 11.8% of the respondents had no education, primary education, secondary education, higher-secondary education and graduate education, respectively (Table 1). Agriculture, animal husbandry, wage labor and other services were the income sources of about 46.7%, 17.3%, 33.2% and 23% of respondents, respectively. The landless households, dryland farmers and rainfed farmers were mostly dependent on wage labor income for their livelihoods.
Table 1. Socio-economic characteristics of the households.

| Household (HH) Characteristics | Landless Category | Dryland Farmers | Rainfed Farmers | Less Irrigated Farmers | Medium Irrigated Farmers | High Irrigated Farmers | Average |
|--------------------------------|------------------|-----------------|----------------|------------------------|--------------------------|-----------------------|---------|
| Households proportion (%)     | 23.4             | 14.6            | 32.8           | 16.4                   | 8.7                      | 6.9                   | -       |
| Average age of HH             | 47.3             | 45              | 49.2           | 44                     | 46.5                     | 45.8                  | 46.3    |
| Average HH/family size        | 4.8              | 4.6             | 4.3            | 4.7                    | 4.3                      | 4.4                   | 4.5     |
| Education (%)                 |                  |                 |                |                        |                          |                       |         |
| No education                  | 8                | 6               | 11             | 7                      | 9                        | 3                     | 7.3     |
| Primary                       | 26               | 36              | 28             | 31                     | 22                       | 34                    | 29.5    |
| Secondary                     | 32               | 29              | 34             | 27                     | 29                       | 30                    | 30.2    |
| Higher                        | 27               | 16              | 24             | 14                     | 27                       | 19                    | 21.2    |
| Collegiate (Graduate)         | 7                | 13              | 3              | 21                     | 13                       | 14                    | 11.8    |
| Source of HH income (%)       |                  |                 |                |                        |                          |                       |         |
| Agriculture                   | 6                | 32              | 44             | 52                     | 68                       | 78                    | 46.7    |
| Animal husbandry              | 12               | 17              | 18             | 22                     | 16                       | 19                    | 17.3    |
| Wage labor                    | 78               | 56              | 33             | 16                     | 12                       | 4                     | 33.2    |
| Services and others           | 16               | 17              | 19             | 21                     | 27                       | 38                    | 23      |
| Average land holdings (HH in acres) | -       | 4.6             | 3.8            | 4.2                    | 3.7                      | 7.2                   | 3.25    |
| Average livestock (HH)        | 2                | 1               | 3              | 2                      | 1                        | 2                     | 2.5     |
| Gross annual HH income (USD)  | 849              | 1107            | 1649           | 2196                   | 2359                     | 3158                  | 1886    |

The average size of the farm holdings was 3.25 acres, the mean average livestock holding was 2.5 animals per household, and the average annual household income of each respondent was USD 1886. The landless, dryland and rainfed farm households’ average annual gross income was further below the average annual gross income. The results coincide with the findings of Udmale et al. [18]. Among the different respondents’ socio-economic status, the household size and educational status were relatively similar in all categories, except the collegiate education; hence, the school level education was mostly accessible from the nearby villages or town level public sector centric educational institutions, while the economic status decided the collegiate education status (7–21%). Households’ income in landless household categories mostly came from the wage employment from agricultural sector. In the current study, the income of the households ranged between USD849 and 3158 with the mean average of USD 1886/household, which decides the spending behavior and equally the dependency on the public sector social welfare schemes. The landless and dryland households were mostly dependent on wage labor income opportunities, and the climate change-induced drought impacts severely affected the landless and rainfed farmers, more so than the irrigated farmers. Hence, based on the households’ socio-economic status, the individual perceptions against the climate-change induced drought impacts, and the relevant adaptation and mitigation strategies might have also differed in semi-arid pastoral and agricultural watersheds of Southern India.
3.2. Farmers’ Perception on Climate Change (Drought) Impacts

Among various climate change impacts, drought is the major issue faced by farmers, as it affects their livelihoods in semi-arid regions of Southern Indian watersheds (Figure 2). The farmers responded that they have received less and uneven rainfall, reduced intensity of rainfall or no rainfall in the monsoon seasons, which has affected their agricultural and allied livelihood activities over the last 30 years [18]. They also responded to perception-based responses about drought impacts viz. drying of water resources (84%), reduced water supply (72%), reduced surface and groundwater sources (66%), partial crop failures (58%), decline in livestock prices (42%), complete crop failure (42%), degradation of landscape quality and soil erosion (36%), increased food prices (34%), insect infestations and plant diseases (33%), loss of agro-biodiversity (28%), poor health of animals (21%) and loss of livestock (12%), respectively (Figure 2). These results also coincide with the findings of Raza et al. [21]. The farmers also perceived that the deforestation, encroachment of water bodies, discouragement of cultivation of less water consuming crops (millets/pulses/oilseeds), encouragement of cultivation of high water-consuming crops (vegetables/rice/sugarcane), mismanagement of water resources, and increased bore wells as the major reasons for the severity of the drought in the region. The results coincide with the findings of Muralikrishnan et al. [19]. Moreover, in recent past, irrigated agriculture had a positive and important impact on aggregate agricultural and other allied sectors production. Hence, the current drought situation in the semi-arid pastoral and agricultural watershed areas requires effective adaptation and mitigation strategies for sustainable agricultural production under prevailing climate change and weather variability. Further, the development of alternative livelihood systems may support in coping-up the changing climate to transform the agricultural production systems and sub-sectoral diversification of agricultural production and off-farm activities of processing and marketing support to maximize the agricultural livelihoods and economic development of the region [20].

![Figure 2. Perception on climate change (drought) impacts among the respondents of Southern India.](image)

3.3. Percent Reduction in Area and Production of Various Crops in Southern INDIAN Districts

The farmers (n = 400) reported substantial reduction in cropped area among major crop categories of cereals, millets, pulses, oilseeds, commercial crops, horticultural and fodder crops. The average cropped area reduction indicated that the commercial crops such as cotton (26%), millets viz. pearl millet, finger millet and other millets (22%), and sorghum (18%); have shown reduction in acreage due to changed cropping patterns. Millet acreage showed reduction due to reduced millet-based consumption patterns in the semi-arid regions. The other crops’ area viz. pulses (6%), oilseeds (4%), horticultural crops (4%) and fodder crops (1%) reduced minimally (Figure 3), due to the lowest drought impacts on these crops [6]. The climate change impacts viz. reduced rainfall, continuous dry spells, severity of the droughts in various selected districts’ agro-ecologies, considerably reduced.
the cropped area under various crops in the region (Figure 3). Such results were also observed by Raza et al. [21].

![Figure 3. Percent reduction in various crops’ area among the respondents of selected districts of Southern India.](image)

The farmers reported a reduction in average crop production of all the major crop categories of cereals, millets, pulses, oilseeds, commercial crops, horticultural and fodder crops. The average crop production reduction was highest in commercial crops such as cotton (29%) followed by millets, such as pearl millet, finger millet and other millets (26%), cereals such as sorghum (16%), all due to the reduced cropped area and drought related production impacts [6]. The pulses (5%), oilseeds (5%), horticultural crops (5%) and fodder crops (2%), registered the least reduction in average crop production due to least reduction in the cropped area and the lowest drought impacts (Figure 4). Major reasons for the reduction in production and productivity in the drought-affected semi-arid region are the early-season and mid-season droughts that cause more production losses [6]. Moreover, such crops as cotton and millets, and particularly sorghum, incur more production expenditures on farm labor for intercultural operations. Moreover, the market for these commodities vis-à-vis their demand from the consumption point of view is entirely different from the regularly consumed cereals, such as rice and wheat. Hence, the farmers showed the least interest to go in for their high yielding varieties and costly intercultural operations. Further, the respondents responded that due to the drought impacts, the arable land was kept fallow, which encouraged the long-term forest plantations [11]. Moreover, the Indian semi-arid regions require improved drought monitoring and early warning systems, particularly for agricultural drought assessment as an integrated agro-climatological drought mitigation measure. For example, in the semi-arid Marathwada region of India, the satellite and model-based input parameters were analyzed at a monthly scale from 2001 to 2018 which depicted moderate to extreme drought cases in the years 2002, 2009 and 2015–2016, with significant increase in drought intensities and drought frequency over the years 2001–2018. Similarly, the Chennai meteorological station in Tamil Nadu also reported from the data of the last 30 years (1989–2019) that the warmer days and dryness in weather increased and the rainy days reduced in the semi-arid regions of Tamil Nadu, India [22].
3.4. Farmers’ Perception on Socio-Economic Impacts

Drought-impacted semi-arid regions of Southern India have faced multiple climatic and non-climatic risks [23]. A maximum numbers of households were engaged in the pastoral- and agricultural-based rural social settlements and fewer households were engaged in industrial and service sectors for their livelihoods. Hence, the drought impacted their livelihoods and the farmers, relatively, had poor socio-economic status. The farmers reported that the deteriorated socio-economic status led to reduced spending on children’s education (74%), health problems (68%), conflicts for drinking water (68%), seasonal unemployment (46%), population migration (45%), malnutrition (42%), reduction in household income (38%), reduced employment (38%), reduction in household expenditure (36%), household food insecurity (34%), and reduced spending in festivals (18%) to very high socio-economic impacts, reduced spending in festivals (32%), reduced employment (22%), household food insecurity (19%), reduced household expenditure (16%), population migration (14%), reduction in household income (13%) and malnutrition (10%), respectively (Figure 5).

3.5. Households’ Daily Food Consumption Pattern

The drought-led socio-economic impacts affected the household food and balanced-nutrition diet of semi-arid regions of South Indian watersheds (Figure 6). In general, the drought affected the (i) food availability due to reduced agricultural production, (ii) food access due to poor affordability of food, and (iii) accessibility of quality food grains utilization with food safety and standards [6,24]. The farmers reported that the daily food consumption was affected severely, as compared to recommended (WHO) healthy
dietary practices [25]. The cereals (41%), pulses (45%), oilseeds (40%), milk (57%) are in the daily routine of the households’ food habits. Further, the households consume processed products (46%) and vegetables (70%) on a weekly basis; fruits (82%), eggs (77%) on a fortnight basis; and non-vegetarian diets (79%) and fish (92%) on a quarterly or half-yearly basis. Hence, the consumption of food items such as fish, fruits, non-vegetarian items like meat and chicken, processed products, vegetables and eggs, was poor among the households (Figure 6). It is all due to reduction in local food systems and increased food prices [26]. Less food intake also led to poor food consumption pattern, thus, leading to reduced food intake and nutrition insecurity due to less per capita food consumption [3,26]. Most of the households relied upon purchased cereals, vegetables, fruits, and animal source foods in the drought affected semi-arid regions of south Indian watersheds. However, it was observed that the public sector social programs such as the public food distribution system, rural employment programs, mid-day meal schemes for school children, and integrated child development schemes collectively supported the rural masses to reduce the nutrition insecurity issues in the region [26]. Hence, the drought impacts affected the physical, socio-economic and food consumption status which can be linked to environmental, behavioral and developmental economics principles of the developing nations [6,11,26]. Moreover, behavioral studies provide more realistic models of human behavior to recognize the present issues to make decisions in challenging situations. Hence, studying the farmers’ behavior is an effective tool to make use of appropriate adaptation and various mitigation strategies for climate resilience while improving public policy, programs and processes [27].

![Processed products (Purchased) 2012-2022 processed products (Home)](image)

Figure 6. Daily food consumption pattern among the respondents of Southern India.

3.6. Farmers’ Usage of Weather Information to Agricultural and Pastoral Activities

The farmers’ usage of weather information plays a very important role in drought adaptation, mitigation and effective management of agricultural activities through increased public awareness so as to understand the drought situations and encourage them to get involved in reducing the drought risks [6,27]. The electronic and print media bridge the gap between the farmers and weather forecasting stations to access timely and relevant information in short-term, medium-term and long-term crop calendar preparations so as to reduce the drought risks [3]. Most of the farmers access the production led agro-advisories from the input dealers followed by innovative farmers, media sources and public sector agro-advisories. With respect to the weather information, most of the farmers follow their ancestors’ indigenous technical knowledge for their pastoral and agricultural activities, particularly, the time of sowing and harvesting operations. So, the respondent farmers placed less importance to the weather information-based agro-advisories. The farmers reported that they usually accessed weather information through television (28%), followed by neighbors or relatives (26%), radio (16%), mobile-based agro-advisory (12%), public sector agricultural science centers (Krishi Vigyan Kendras (KVKs)) (12%), community radio (3%), village information system (3%) and gram-panchayats (2%), respectively (Figure 7).
It shows that the farmers had poor access to weather information for their agricultural activities. To improve the existing conditions, the public sectors and other development stakeholders in the agricultural sectors must be given high priority for timely delivery of the weather-based information support to the farmers [3]. The drought mitigation and adaptation through weather-based crop insurance schemes and other alternate climate-resilient varieties and the recommended climate-smart agronomic practices also need urgent attention [3,28]. Hence, improvement in weather information usage through promotion of weather-based agro-advisories and climate smart agricultural practices through awareness/training program can support effective adaptation and mitigation practices in semi-arid regions [24].

Figure 7. Farmers’ usage of weather information to agricultural and pastoral activities in Southern India.

3.7. Farmers’ Social Participation Level

The social participation level of farmers plays a very important role in climate-smart agricultural technologies adaptation and mitigation measures [29]. The rural community has better social cohesion, which enhances the peoples’ participation level in the community development processes in a sustainable manner [26]. It can reduce the social and economic impacts of droughts in the semi-arid watersheds of South India. It can support local communities to build self-reliance and preparedness to manage drought consequences [23]. In the current study, the farmers participation level was mainly in death funerals (92%), village festivals (86%) and family functions (74%), with less social participation level in the formal socio-economic activities such as engagement in self-help group (SHG), participation in extension activities (26%) and other government and non-government schemes (24%), farmers’ cooperatives and farmers’ producer companies (22%), farmers’ clubs (17%), agricultural technology management agency (ATMA) activities (14%), gram-sabha (12%), village development committees (8%), etc. (Figure 8). The intensive agro-advisories and awareness/training programs may improve the peoples’ participation level in drought adaptation and mitigation activities in the semi-arid watersheds of Southern India. The respondents’ effective social participation level may create better social, knowledge and extension networks among the farmers’ social settings and it may also enhance the awareness and knowledge level for better climate adaptation and mitigation strategies.
3.8. The Farmers' Extension Agency Contact

The farmers' extension agency contacts can easily identify the drought impacted problems to help farmers to adopt and practice various climate smart agricultural practices for adaptation and mitigation purposes [29]. It also identify the farmers’ preferences for various extension approaches to motivate them to attend the extension education trainings for effective drought adaptation and mitigation related climate-resilient extension services to small-scale farmers [30]. Hence, this study can assess the relative importance of different extension agency contacts to increase their effectiveness in agricultural extension services with regard to drought-related climate impacted adaptation and mitigation practices [31]. Thus, in this study, it was reported that the farmers were mostly engaged with private input dealers (65%) followed by neighbors (47%), extension officers of state department of agriculture (36%), radio (26%), television (22%), mobile based advisory (14%), Farm Science Centers (Krishi Vigyan Kendra (KVK) scientists) (12%), State agricultural universities (SAUs) and Indian Council of Agricultural Research (ICAR) institutes’ scientists (8%) and newspapers (8%), respectively for farm information and agro-advisory services (Figure 9). Hence, the farmers’ extension agency contact was mostly reliant upon the private input dealers followed by neighbors for farm communication. Very less extension agency contact was found for mainstream extension agencies of state department of agriculture, KVK scientists and frontline extension delivery services of SAUs and ICAR scientists. Likewise, fewer farmers obtain the mainstream mass media-based extension services of radio, television, mobile-based advisory and newspaper-based agricultural information services (Figure 9). Thus, it may adversely affect the efficiency of the extension system for drought related climate-smart agricultural practices vis-à-vis adaptation and mitigation purposes [32]. Hence, there is a need to scale-up the farmers’ extension agency contact level in drought areas for better adoption of climate-smart agricultural practices in the semi-arid watersheds of Southern India.

Figure 8. Social participation level (%) among the respondents of Southern India.

Figure 9. Extension agency contact levels among the respondents of Southern India.
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3.9. Farmers’ Adaptation against the Drought Impacts

The drought adaptation supports and adjusts the ecological, social, or economic systems in response to the expected drought impacts through changes in the regular processes, practices, and arrangements to benefit the ecological and socio-economic aspects of the particular region [3,6]. It varies based upon the general watershed characteristics, frequency of droughts in the study area, availability of appropriate drought warning systems, availability of water storage structures, cropping patterns in the watersheds, and water supply and distribution infrastructures to minimize environmental impacts [4,33,34]. In our study (Figure 10), the farmers also practiced the drought adaptation practices; and overall, a third of farmers were involved in crop residue storage for livestock as a drought adaptation practice (36%), 1/5th of our farmers practiced healthy drought adaptation practices viz. crop produce storage for food purpose (22%), farm mechanization (22%), saving money (19%), adjusting dates of cropping calendar (11%), promotion of alternate livelihoods (18%), crop insurance (17%), early sowing practices (16%), cultivation of less water consuming crops (16%), crop diversification (14%); and less than 1/10th of farmers followed construction of small check dams (7%), as healthy drought adaptation practices (Figure 10). The farmers also practiced seasonal migration for alternate livelihood opportunities (34%) which cause rapid urbanization and slum-based settlements and fallowing of arable lands (28%). It further leads to land degradation due to poor maintenance of the pastoral and agricultural lands [6]; it also helps in the flourishing of exotic Prosopis juliflora shrub which adversely affect the land quality in the region [6]. Poor credit accessibility (28%) and dependence on money lenders cause critical financial liabilities to the vulnerable households in the region where easily accessible credit facilities may ameliorate the negative impacts of the droughts. Hence, there is an urgent need to extend effective adaptation strategies for improved livelihood opportunities as an effective drought preparedness measure in semi-arid watersheds of Southern India.

![Figure 10. Adaptation strategies against the drought impacts among the respondents of Southern India.](image)

3.10. Farmers’ Mitigation Measures against the Drought Impacts

Drought mitigation practices are the holistic approaches or techniques or applied means to reduce the risks of economic, social, and environmental drought impacts for attaining ecosystem sustainability in the period of the drought-related aridity [3,4,28]. In current study, it was observed that the social security programs amply supported the drought mitigation practices such as public sector’s rural employment program (Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA)’ program works (87%), public distribution system based food grains’ supply (86%), community initiatives on water harvesting (46%), community initiatives on water sharing (44%), subsidies for agricultural inputs (38%), ex-post compensation (38%), old-age disability pension (32%), free...
electricity for agriculture (18%), enhancing area under agro-forestry (17%), increasing loan beneficiaries (14%) and recommendation of traditional varieties for climate-resilience (12%), respectively (Figure 11). This study revealed that most of the frontline economic upliftment-based appropriate mitigation measures have not reached or were ineffective for more than half of the respondents in the semi-arid watersheds of Southern India. Hence, there is an urgent need to promote and develop more extension centric social development and skill upgradation related strategies for improved mitigation practices in the semi-arid watersheds of Southern India. Effective drought preparedness and mitigation can effectively reduce the impacts of droughts through accurate weather prediction, monitoring the drought situation and assessment of impacts [6]. The technological drought mitigation strategies such as the satellite based geographical information system (GIS)-based information can also play a very important role in the early warning systems, drought monitoring and impact assessment purposes [6,11]. Likewise, effective soil and water conservation, and herd management practices can act as good drought mitigation practices in drylands [7,11,12,35].

**Figure 11.** Various mitigation measures against the drought impacts among the respondents of Southern India.

### 3.11. Regression Estimates for Decision-Making Factors against Drought Adaptation

The results of the binary logistic regression (Table 2) revealed that the educational status, occupational status, perception on climate induced drought and farmers’ knowledge on crop diversification were fairly significant at $p < 5\%$ level among all the independent variables. Hence, these variables may play an important role in farmers’ decision-making power against various climate-change adaptation processes [6]. This indicates that an increase in the educational status of farmers had positive impact on the decision making related to the climate-change adaptation processes in the semi-arid watersheds. Improved educational status with the support of various public sector-based educational schemes in the region played a pivotal role in better adaptation against the climate-induced drought impacts. Improved occupational status through agricultural and other alternate employment opportunities also provided better financial upliftment of the households. All these factors led to accelerated adaptation strategies against the drought impacts in the semi-arid watersheds (Table 2). It was also observed that older farmers mostly relied upon indigenous technical knowledge against the climate adaptation, while their younger family members supported them through digital weather information services for better adaptation. Hence, the action-oriented perception on climate-change adaptation plays an important role in effective drought adaptation preparedness. The farmers’ knowledge on crop diversification also played an important role in selection of crops, alternate cropping patterns and alternative livelihood options as adaptation measures in the semi-arid watersheds. Hence, the statistical analysis revealed that there is a significant relationship between the
socio-economic variables and climate induced drought adaptation measures, and thus, the alternative hypothesis was accepted for the study.

Table 2. Regression estimates for decision-making factors against drought adaptation (n = 400).

| S.No. | Profile Characteristics | Binary Logistic |
|-------|-------------------------|-----------------|
|       |                         | B               | Sig           |
| 1     | Age                     | 0.114           | 0.735         |
| 2     | Educational status      | 1.973           | 0.020**       |
| 3     | Occupation status       | 0.236           | 0.047**       |
| 4     | Annual income           | 0.636           | 0.425         |
| 5     | Land holding size       | 0.069           | 0.792         |
| 6     | Social participation level | 0.099       | 0.753         |
| 7     | Perception on climate induced drought | 4.020 | 0.045**       |
| 8     | Access to weather information | 0.490   | 0.227         |
| 9     | Knowledge on crop diversification | 1.462 | 0.024**       |
|       | Overall statistics      | 10.228          | 0.783         |

*Significant at p < 5% level.

4. Conclusions

Periodic drought is the major challenge in drought prone areas of southern India. Over last five decades, the government of India has executed various watershed development schemes in semi-arid watersheds of south India. However, farmers’ active participation, effective monitoring and linkages with agricultural agencies, and water bodies’ sustainable utility, etc., are some of the critical issues which are not being dealt with well. At the same time, farm level in-situ soil and water conservation activities are also not being well maintained in watersheds. In the study area, frequency of droughts, severity of droughts, reduced rainfall, continuous dry spells, etc., are the main factors which reduced the cropped area in various crop categories, which further affected the socio-agro-economic status of agricultural-based rural settlements, as per the current study. About 16–26% farmers responded that droughts reduced the area and production of commercial crops and millets in drought-prone areas, while there is less impact on the changes in the cropping patterns of pulses, oilseeds, horticultural and fodder crops. These factors also impaired the local food systems. About 57–92% respondents showed a reduction in the consumption of fruits, vegetables, dairy products and fish, etc. Likewise, there is a decrease in surface and ground water availability, soil degradation, partial crop failures, increased agricultural fallows and wastelands, loss of biodiversity, and decrease in agricultural yields. Unemployment, migration, reduced farm incomes and malnutrition are major socio-economic impacts among respondents (38–46%). Farmers had poor participation related to agri-information (8–65%) and adaptation measures (7–36%) against drought impacts. Poor weather information access and negative drought adaptation, such as fallowing of fields and migration, further impaired the livelihoods. However, public sector-sponsored social security program greatly supported the livelihoods in the watersheds.

The farmers also followed the adaptation practices like crop residue storage for livestock (36%), farm produce storage for food purpose (22%), farm mechanization (22%), adjusting dates of cropping calendar (11%), promotion of alternate livelihoods (18%), crop insurance (17%), early sowing practices (16%), cultivation of less water consuming crops (16%), crop diversification (14%) as some of the healthy drought adaptation practices. An increase in the educational status, occupational status, and action-oriented perception on
climate-induced drought adoption practices and farmers’ knowledge on crop diversification emerged as few important determinants for a positive decision-making process against the climate change adaptation process in semi-arid watersheds. Hence, appropriate educational and training program on various livelihood opportunities and drought adaptation measures are highly essential in the study area. In addition, for effective drought preparedness and mitigation, the administrative measures, such as subsidies on agricultural inputs, ex-post compensation, increased loan beneficiaries and recommendation of traditional varieties for climate-resilience, also needed urgent attention in the region. Peoples’ participatory GIS-based watershed management with regard to common property resources of water bodies and wastelands is also the need of attention. For effective drought preparedness and mitigation, the administrative measures, such as subsidies on agricultural inputs, ex-post compensation, increased loan beneficiaries and recommendation of traditional varieties for climate-resilience, also needed urgent attention in the region. Peoples’ participatory GIS-based watershed management with regard to common property resources of water bodies and wastelands is also the need of attention. For effective drought preparedness and mitigation, the administrative measures, such as subsidies on agricultural inputs, ex-post compensation, increased loan beneficiaries and recommendation of traditional varieties for climate-resilience, also needed urgent attention in the region.

5. Recommendations

- Climate smart agricultural practices-based awareness and knowledge dissemination mechanisms may enhance the farmers’ knowledge against drought adaptation. Encouragement of mass media (radio, television) and other mainstream information and communication services through smart mobiles may play an important role in quick dissemination of drought adoption practices to upscale farmers’ capabilities in this context.
- Promotion of less water-consuming crops, such as millets, pulses and oilseeds, is highly needed in the semi-arid pastoral and agricultural watersheds of Southern India. For that, the implementation of special policies, such as minimum support prices (MSP), for these crops may accelerate their acreage so as to improve climate-resilience and livelihood security in drought-affected semi-arid watersheds of South India. Hence, the promotion of public sector-based MSP-based procurement systems may be provided to the rural poor and marginalized farmers. This mechanism will provide a remunerative and competitive price to the farmers and likely will be effective in addressing climate resilience and malnutrition-related issues.
- Implementation of various farm level in-situ and watershed level (pond/tank-fed or farm pond-based) soil and water conservation practices and other eco-friendly agricultural practices to conserve the rainwater and enhance the water retention capacity in the region. For example, the semi-arid regions accessing water from less numbers of rainy days (1/10th of rainy days/annum). Thus, in-situ soil and water conservation at watershed level may effectively support in the remaining periods of drier seasons.
- Complete ban on conventional flooding practice and high water-consuming crops’ cultivation in the drought-affected semi-arid watersheds of southern India and similar agro-ecologies all across. The drip- and sprinkler-based micro irrigation provides ~80–90% water-use efficiency; hence, encouraging these irrigation systems with the support of public policies, private sectors and farmers polices may act as an effective adaptation strategy in the semi-arid regions.
- Promotion of rainfed integrated farming systems and other crop diversification practices for effective energy conservation in the drought affected semi-arid watersheds of southern India. For example, the promotion of the agriculture–dryland horticulture–forestry goat- and cow-based integrated model may act as an effective drought adaptation strategy in semi-arid agro-ecologies. Hence, the promotion of alternate livelihood opportunities may strengthen the farmers’ occupational status.
• The crop insurance products and drought relief-based ex-post facto compensation is also suggested to sustain the climate-smart agriculture in drought-affected semi-arid watersheds of Southern India.

• Researchers, extension agents and policymakers must develop ‘people’s participatory mode’ drought adaptation and mitigation policies in watershed-based semi-arid pastoral and agricultural regions of Southern India and all collateral agro-ecologies. In addition, due importance should be given to other development stakeholders, such as NGOs and the private sector, for effective climate change-induced drought adaptation and mitigation in semi-arid regions of South Asia and similar agro-ecologies across the globe.

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