Water Scarcity and Drought
https://www.sciltp.com/journals/wsd

Review

Impact of Floods and Droughts on Food Security in Nepal: A Systematic Review

Kumar Aryal [1,*], Dhiraj Pradhananga [2] and Deepak Aryal [1]

[1] Central Department of Hydrology and Meteorology, Tribhuvan University, Kathmandu 44600, Nepal
[2] Department of Meteorology, Tri-Chandra Multiple Campus, Tribhuvan University, Kathmandu 44600, Nepal
* Correspondence: kumarandphd@gmail.com; Tel.: +977-984-185-4801

How To Cite: Aryal, K.; Pradhananga, D.; Aryal, D. Impact of Floods and Droughts on Food Security in Nepal: A Systematic Review. *Water Scarcity and Drought* **2025**, *1*(1), 2.

Received: 1 Apr 2025
Revised: 22 May 2025
Accepted: 23 June 2025
Published: 25 June 2025

Abstract: This study presents a systematic review of 53 peer-reviewed articles published between 1979 and 2024 to evaluate the impacts of floods and droughts on food security in Nepal. This review employs the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) framework to systematically evaluate the impact of hydroclimatic extremes on the four aspects of food security: availability, access, utilization, and stability, going beyond simple narrative synthesis. The review reveals increasing trends in the frequency and severity of both floods and droughts, with substantial impacts on agricultural productivity, market access, infrastructure, and rural livelihoods. Compound events, where floods and droughts co-occur or follow one another, further destabilize food systems. Descriptive analysis showed that most studies were concentrated in recent years, with a dominant focus on floods over droughts, and limited integration of both hazards with food security outcomes. The majority of studies (74%) employed quantitative methods, but few examined the combined socio-environmental drivers of food insecurity. The review identifies significant gaps in the current literature. It highlights the inadequate incorporation of socioeconomic variables within climate risk models, a deficiency in the availability of real-time and high-resolution data, the insufficient representation of marginalized populations, and the lack of longitudinal studies examining nutrition and health outcomes. A limited number of studies specifically focus on the various ways hydroclimatic extremes influence food security. This review offers new perspectives by thematically categorizing impacts based on food security dimensions and emphasizes the critical need for localized, integrated, and adaptable policy measures. The results provide a foundation for more thorough research and strategic planning aimed at improving resilience to climate-related food insecurity in Nepal.

Keywords: hydroclimatic extremes; PRISMA framework; Nepali agriculture; food security

1. Introduction

As a landlocked country in South Asia, Nepal is one of the most prone countries to climate change-induced disasters, including floods and droughts [1–3]. This susceptibility is because of the country's geographical features, such as the lowland plains up to the high Himalayan region. Extensive research has documented that these natural disasters have significant effects on the food security of the people in Nepal [4–7]. It is important to realize that climate change has a direct and perhaps stronger impact on the green sectors of economies than on the rest of the economy. Agriculture production is one of the forms of production that bases its operations on natural resources; hence, it is an easy target of extreme weather occurrences.

Due to floods and droughts, there are always massive losses in crop and livestock production, the major production units of the agricultural sector in the country. Being an agricultural country, these losses have a significant effect on the overall development and food security of the people in the country [8,9]. However, these events commonly hinder food supply and restrain market entry, thereby posing problems in food distribution across the nation. The socioeconomic impacts of these calamities are multi-faceted, with adverse impacts on the cost of food leading to the unavailability and unaffordability to many households in Nepal [10,11]. Further to these issues, climate change forecasts point to an increase in the intensity and frequency of these extreme weather incidents that may further complicate the food security issue in the future years.

Different research shows that there have been expected changes in the frequency, duration, intensity, and geographical distribution of precipitation as well as increased frequency, duration, and intensity of drought [12–15]. Climate change impacts on agriculture have become sensitive since agriculture yields food as well as a source of income for large sectors of weaker segments of society. A report by the Food and Agriculture Organization (FAO) shows that climate change impacts on food security will be experienced across all four dimensions, including availability of food, access, utilization, and stability [16,17].

The FAO defines food security as a situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life [18]. These four dimensions encompass: food availability (the supply of food through domestic production, import, or food aid); food access (households and individuals have adequate resources to obtain appropriate foods for a nutritious diet); food utilization (the way the body makes the most of nutrients in food, which is influenced by food preparation, diversity of the diet, and health status); and food stability (access to adequate food at all times and individuals should not risk losing access to food as a consequence of sudden shocks or cyclical events) [19]. This means that, if climatic factors worsen agricultural production in Nepal, the living standards of two-thirds of the workforce, especially the rural poor, would be further compromised.

Despite the extensive literature on floods, droughts, and their impact on food security, there remain significant gaps in understanding, particularly in Nepal, regarding the long-term health effects of these disasters. While the direct impacts of such events are somewhat documented, the cumulative physical health consequences are not well understood. Moreover, there is limited evaluation of existing risk reduction and adaptation measures related to climate-induced food insecurity. Previous reviews addressing hydroclimatic extremes and food security in Nepal have largely concentrated on drought and crop yield, presenting mostly narrative analyses [5,20–22]. Consequently, the focus on floods and their impacts, the direct effects of drought on the four pillars of food security, and the combined effects of both floods and droughts on food security have largely gone unexplored.

This review aims to address these gaps by synthesizing existing knowledge on the historical and projected impacts of floods and droughts on food security in Nepal. It evaluates the implications of these disasters for agricultural systems and rural livelihoods and highlights critical deficiencies in current literature, particularly regarding nutrition and public health. Additionally, the review examines the effectiveness of present-day adaptation and mitigation strategies while exploring opportunities to enhance Nepalese food systems' resilience to future climate shocks. Importantly, this review not only focuses on the narration of the existing literature, it rather focuses on the rigorous scientific process aimed at providing a reliable and unbiased answer to a specific question related to drought, flood, and food security. By addressing these issues, this review provides a comprehensive understanding of how floods and droughts affect food security in Nepal, identifies key research gaps, and offers recommendations to guide future research and policy development aimed at improving agricultural and food systems in the face of climate variability.

2. Methodology

This systematic review examines peer-reviewed research on drought, flood, and food security in Nepal from 1979 to 2024. A total of 53 original research articles were selected after applying a structured search strategy, inclusion/exclusion criteria, and quality assessment. Additionally, three national reports, the Nepal Living Standard Survey IV (2022–2023) [23], Nepal Demographic and Health Survey report [24], and Global Hunger Index report [25] were included for contextual relevance. The three reports have been integrated to offer nationally representative, current statistics that enhance and contextualize the findings of peer-reviewed literature, especially in areas where academic studies are scarce or do not capture the latest trends. Their inclusion guarantees a more thorough understanding of the current food security challenges, nutritional outcomes, and economic conditions in Nepal, which are essential for interpreting the effects of climate-induced hazards on livelihoods and well-being.

2.1. Search Strategy and Selection Criteria

A comprehensive literature search was conducted using Google Scholar, Scopus, and PubMed. Searches were restricted to articles in English with the term all in the title: Nepal Drought OR Flood OR "Food Security" OR "Hydroclimatic Extremes", and 'Flood Nepal'.

On 1 July 2024, an initial search for relevant articles was conducted across several databases. Google Scholar returned 677 articles, Scopus provided 211, and PubMed retrieved 16. After refining the search with additional keywords, we identified an additional 263 articles from Google Scholar, 107 from Scopus, and 3 from PubMed. Furthermore, 10 highly relevant articles were manually added, resulting in a total of 1287 articles identified for screening.

2.2. Inclusion and Quality Assessment

To maintain a transparent and reproducible review process, the selection and evaluation of studies adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [26]. These guidelines provide a standardized framework for identifying, screening, and including relevant literature in systematic reviews. During this process, we excluded duplicate records (n = 599) and inaccessible entries (n = 11), which included articles that could not be opened or that were not available, despite efforts to obtain them from the authors. Additionally, non-original research, such as reviews, conference papers, book chapters, and reports, was removed from consideration. After screening titles and abstracts for relevance, a total of 53 original research articles were ultimately retained for final analysis.

2.3. Data Extraction

In this phase, 53 articles were selected, and the characteristics extracted were:

(a) Articles must be original papers. Review papers, conference papers, published reports, case studies, and book chapters were excluded.
(b) The articles must be in the English language and relate either to drought, flood, or food security.
(c) Extracted articles were published between 1979 and 2024.
(d) The extracted articles were for Nepal only.
(e) The articles must be accessible.

3. Results

3.1. Descriptive Analysis

In this analysis, the identified 688 articles were classified and presented in different categories. At first, the number of articles published per year from 1979 to 2024 till date was identified. It is found that the highest number of publications was in the year 2020 with 66 articles, followed closely by 2022 and 2021 with 63 and 62 publications, respectively. However, no publications were seen in the years 1980, 1981, 1982, 1984, 1987, 1988, 1989, 1990, and 1992.

After this, another analysis was done to find the types of publications among the 688 identified articles. It was found that 437 articles were original research papers, 53 book chapters, 40 abstracts only, 31 review articles, 25 theses, 22 reports, 21 conference papers, 11 inaccessible documents, 8 case studies, and 37 other articles (Figure 1).

Another descriptive analysis was done to find out the number of citations in the identified publications per year. It was found that the most number of citations was recorded in the year 2017, followed by the year 2010.

After analyzing 437 research articles, the study areas were classified as the whole of Nepal, provinces, river basins, topographic regions, and others. The whole of Nepal had the highest number of studies, with 176 articles. The Himalayan region followed with 45 studies, and Bagmati province had 30 studies.

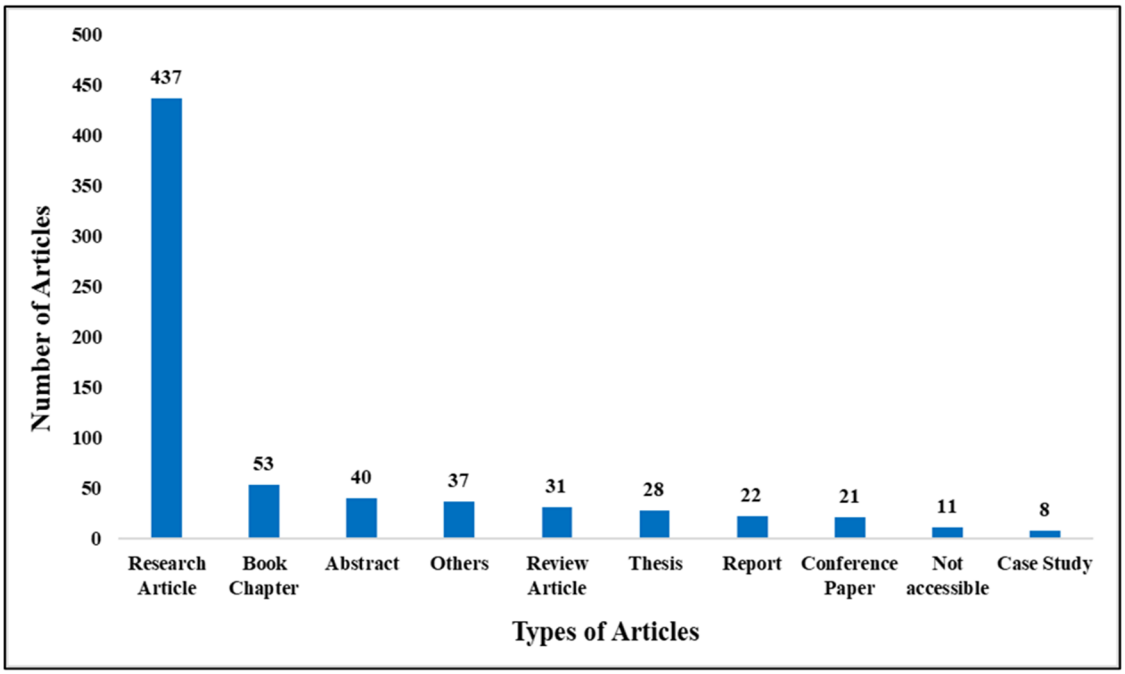

Figure 1. Types of publications among identified non-duplicate items.

3.2. Literature Classification

After conducting a descriptive analysis, we classified 437 research articles by subject area. Out of these, 186 focused solely on flood, 149 on food security, and 39 on drought. Additionally, there were 38 studies on 'drought and agriculture', 16 on 'climate change and food security', 6 on 'drought and flood', and 3 on 'flood and agriculture'. These classifications are illustrated in Figure 2.

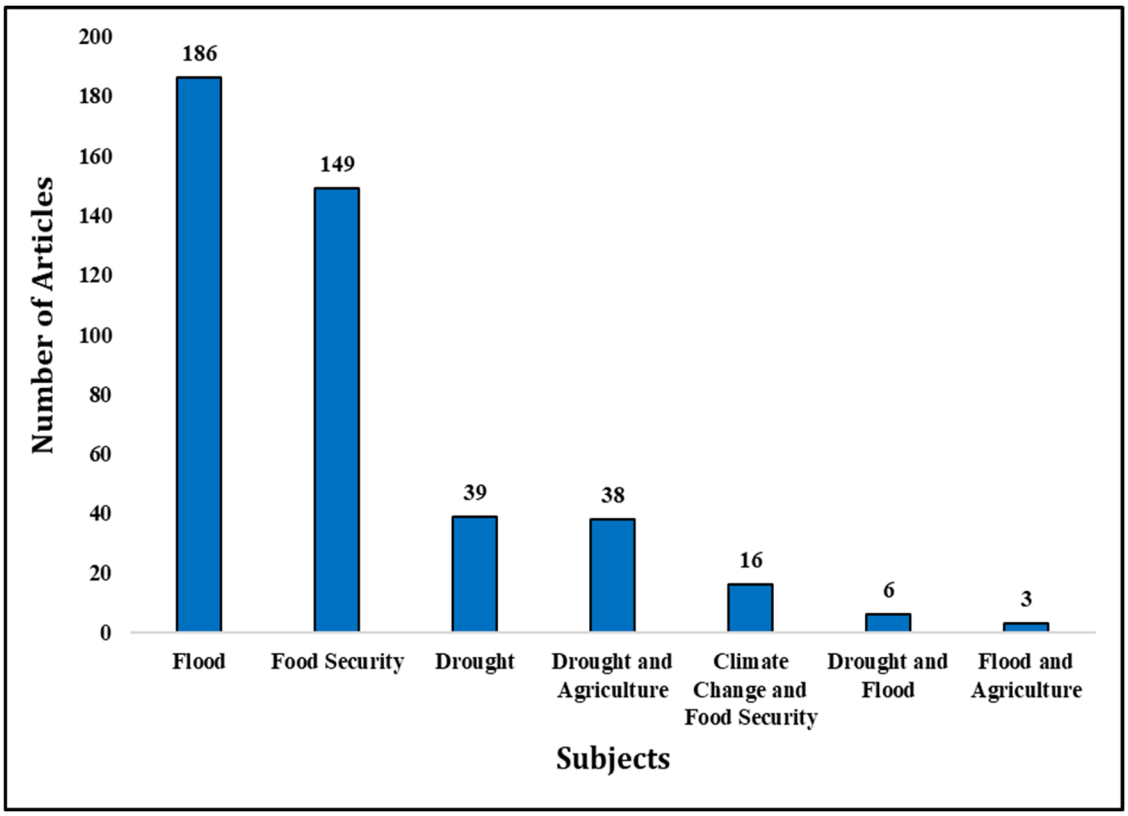

Figure 2. Research articles classified according to subject area.

A classification of drought-related literature has identified three primary indices used to quantify drought conditions: the Standardized Precipitation Index (SPI), which has been featured in a total of 11 articles; the

Standardized Precipitation Evapotranspiration Index (SPEI), represented in 10 articles; and the Normalized Difference Vegetation Index (NDVI), included in 6 articles. Additionally, some studies have focused on agricultural impacts or other related aspects without utilizing these specific indices.

The analysis revealed three main categories of drought studies: Drought (39 studies), Drought and Agriculture (38 studies), and Drought and Flood (6 studies). Details of these categories and the indices used are shown in Figure 3.

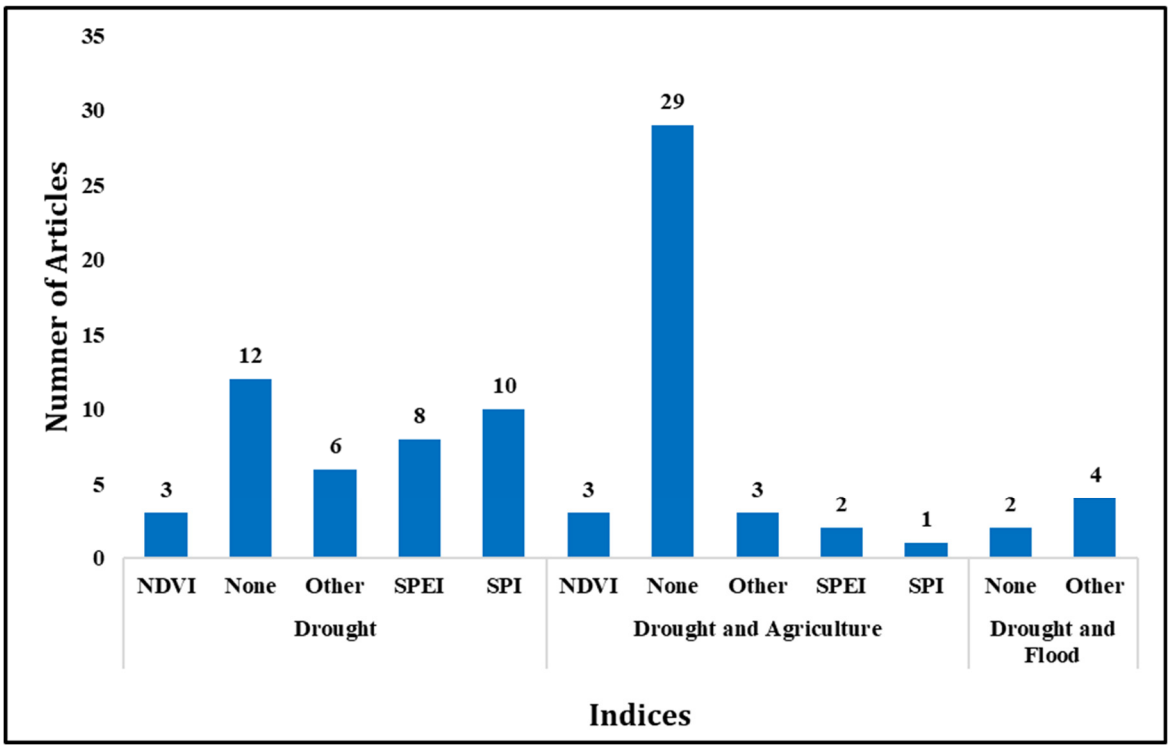

Figure 3. Categories of drought-related articles and number of drought indices used.

A last classification was done for the final included articles for this study. Among the 437 original research articles, only the 53 most relevant articles were selected after a rigorous study of abstracts and methodologies. These 53 articles were classified in terms of their methodology as qualitative, quantitative, and mixed approaches. However, it was found that either the study was quantitative or mixed. In the analysis, 74% of the articles appeared to be following the quantitative method, and 26% remaining articles were following both quantitative and qualitative methods (Figure 4).

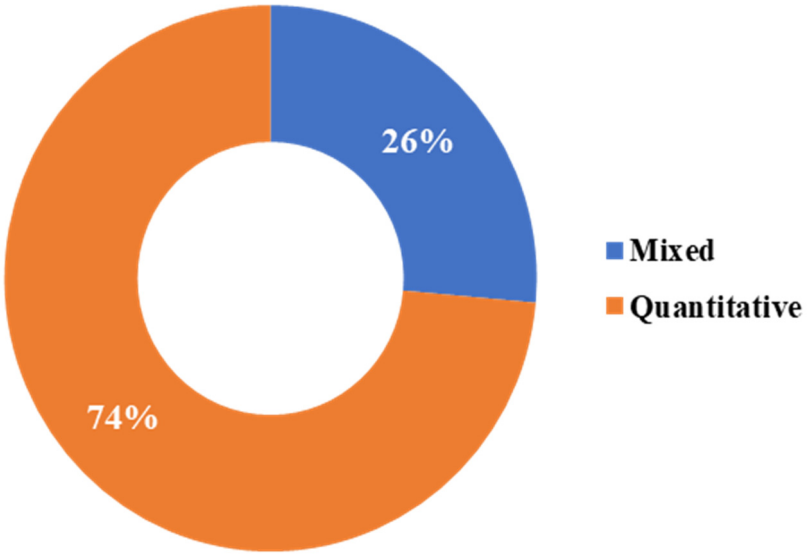

Figure 4. Pie chart showing the percentage of article classification.

4. Discussion

4.1. Overview of Nepal's Vulnerability to Climate-Related Disasters

Nepal is highly vulnerable to natural disasters. Due to its complex physiography and socio-economic conditions, more than 80% of the people of this country are at risk from multiple disasters, including floods [27]. The country's topography, marked by steep mountains and many rivers, makes it especially prone to flood-related disasters. This susceptibility is made even worse by the effects of climate change, which are changing precipitation patterns and amplifying the occurrence and intensity of extreme weather events [28,29]. The country is susceptible to droughts, which have become more frequent and severe in recent decades [30]. Nepal's agricultural sector, reliant primarily on rain, is particularly sensitive to these changes in climate [21]. The occurrence of floods and droughts together poses a major threat to food security, as these events have the potential to devastate crops, harm infrastructure, and disrupt livelihoods.

Additionally, Nepal's vulnerability is exacerbated by socioeconomic factors, including poverty, inadequate infrastructure, and limited disaster preparedness measures. Rural communities, heavily reliant on agriculture for their livelihoods, are especially vulnerable. The country's constrained ability to manage and rebound from disasters amplifies its overall susceptibility to climate-related risks [31]. Figure 5 shows the average annual natural hazard occurrence for 1980–2020 in Nepal, according to the World Bank [32].

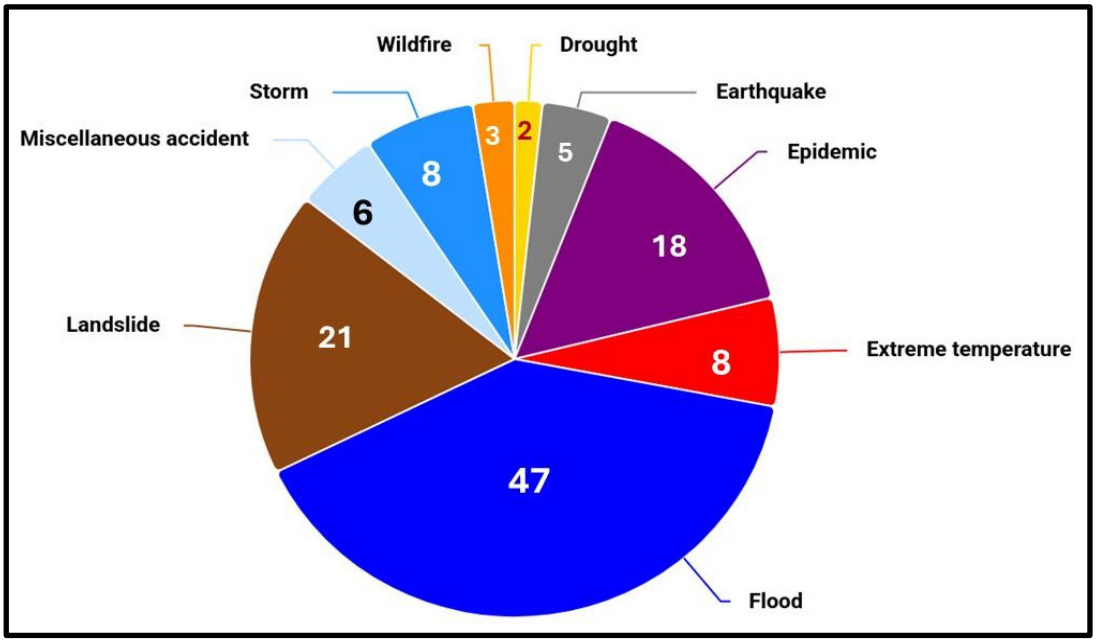

Figure 5. Average Annual Natural Hazard Occurrence for 1980–2020 in Nepal [32].

4.2. Flood Impacts on Food Security in Nepal

Floods are among the most destructive natural hazards in Nepal, significantly impacting the country's food security. These impacts can be effectively understood through the four key dimensions of food security: availability, access, stability, and utilization.

Floods have an immediate and profound impact on food availability, primarily by damaging standing crops and disrupting agricultural cycles. Historical flood events in major river basins such as the Bagmati [2] and Chamelia [33] illustrate how floodwaters can inundate agricultural fields, particularly during critical crop growing seasons. The floods of 2002 and 2004 in the Bagmati Basin notably diminished crop yields in Makwanpur district, a vital agricultural area [2]. Similarly, heavy rainfall from 19 to 21 July 1993, caused severe floods and landslides across central and eastern Nepal, resulting in devastating losses of life, infrastructure, and agricultural land [34]. These events underscore how the loss of arable land directly diminishes local and regional food supplies. In the fertile Terai region, which plays a crucial role in national food production, recurrent flooding significantly disrupts the timing and success of agricultural activities, leading to periodic food shortages. The situation is further exacerbated by projected future flood scenarios, which indicate an increase in flood depth and inundated areas due to climate change [2,35]. With riverbanks expected to be overtopped during various return periods, floodwaters may increasingly invade productive lands, posing ongoing threats to food availability.

In the context of food access, floods severely compromise both the physical and economic capacity of individuals to obtain sustenance. The destruction of transportation infrastructure and market routes during significant flood events hinders the distribution of food supplies, isolating rural communities and disrupting deliveries to urban centers. Research conducted in flood-prone regions like Kanchanpur [36] and Banke-Bardiya [37] indicates extensive damage caused by floodwaters to roads, irrigation systems, and storage facilities. Consequently, food prices may surge, making it increasingly challenging for low-income households to afford adequate nutrition. Additionally, flood disasters tend to exacerbate existing social inequalities and vulnerabilities. Studies focused on socially disadvantaged areas in Nepal demonstrate that post-disaster poverty and marginalization significantly restrict household access to sufficient food [38]. This interplay of factors complicates recovery for already vulnerable populations, such as landless laborers and marginalized ethnic groups, facing flood-induced food insecurity.

Food stability is increasingly threatened by floods, driven by the unpredictability and rising frequency of extreme weather events. Analysis of data from 17 meteorological stations over 30 years (1987–2016) reveals that July consistently experiences peak rainfall, contributing to the annual occurrence of floods in various regions, with probabilities ranging from 67% to 97% [39]. This persistent flooding disrupts farmers' ability to plan their crop cycles and amplifies year-to-year variability in food production. Hydrological studies conducted in the West Rapti Basin corroborate these findings, highlighting significant flood peaks and considerable interannual variation [40]. Future projections indicate that in certain areas of the country, the likelihood of annual floods may reach between 67% and 90%, further destabilizing local agricultural systems [39]. Additionally, modeling studies in the Marshyangdi Watershed suggest that changes in temperature and extreme precipitation events are expected to continue or intensify, posing ongoing challenges for flood prediction and response [29]. In the absence of effective adaptive strategies, such trends will render food production increasingly unstable in flood-prone regions.

And, food utilization, encompassing how food is utilized and its impact on nutritional outcomes, is significantly influenced by floods through environmental degradation. Frequent inundation leads to soil erosion and land degradation, which diminishes soil fertility and compromises the nutritional quality and quantity of future harvests. This deterioration is exacerbated by urban encroachment and unplanned land use in areas like Surkhet and Birendranagar, where valuable agricultural land has been converted for residential and commercial purposes [41]. Advanced modeling tools, such as HEC-RAS, along with statistical methods like GEV distribution, have been instrumental in identifying and predicting these threats by mapping flood-prone zones and vulnerable land types [33,42].

Furthermore, research conducted in the Karnali River Basin employing machine learning techniques has demonstrated a connection between flood risk and topographic as well as vegetative characteristics, providing essential insights for sustainable land-use planning and soil conservation initiatives [31]. Localized flood simulations, such as the Pathariya Khola project, which indicated potential water depths exceeding 4 m during extreme events, further highlight the necessity for site-specific adaptation strategies [43]. Collectively, these studies reinforce the importance of incorporating climate risk assessments into policies aimed at promoting resilient agricultural practices and ensuring nutritional security.

4.3. Drought Impacts on Food Security in Nepal

Droughts, while often less visually striking than floods, present equally significant threats to food security in Nepal. Their gradual onset and prolonged repercussions disrupt food production systems, strain water resources, and challenge household resilience. The effects of drought can be effectively assessed across the four dimensions of food security: availability, access, stability, and utilization. Drought directly impacts food availability by diminishing agricultural productivity and restricting access to water resources crucial for crop development. Historical data from 1977 to 2018 indicate an increasing trend in the frequency of droughts, highlighting a persistent threat to food production [44]. Research has identified eight major drought events occurring between 1980 and 2016, with a notable rise after 2005 [45]. These droughts have disrupted planting and harvesting schedules, particularly during vital growing seasons.

Severe droughts in the years 1992, 2006, 2009, 2012, and 2015 [6] coincided with summer and winter crop seasons, leading to significant reductions in the yields of staple crops like maize and wheat. Additional studies have shown that most years since 2005 have been categorized as dry, with only a few exceptions, such as 2008 and 2011, experiencing humid conditions [46]. The adverse effects of drought have been particularly evident in the far and mid-western regions, where incidents in 1992, 1994, 1999, 2006, and 2010 had widespread repercussions for agricultural production [47]. These trends underline an increasing challenge to maintaining a consistent and adequate food supply in drought-prone areas of Nepal.

In addition to restricting food production, droughts severely undermine access to food, both physically and economically. Repeated crop failures due to droughts result in food shortages and escalating food prices, particularly in vulnerable rural areas. Households that rely on agriculture for both their income and sustenance are the hardest hit, as income losses coincide with the necessity to purchase food at higher prices. Regions in the far and, Dadeldhura, and Jumla, have frequently faced drought conditions [47], exacerbating their economic and food access challenges.

Droughts also diminish seasonal employment opportunities for farm laborers, further constraining income for landless and marginalized households. With inadequate irrigation infrastructure and limited food reserves, these populations are at greater risk of food insecurity during extended dry spells [48]. Urban consumers are not immune; they also experience food price volatility when rural production declines. This situation demonstrates how drought-induced supply shocks ripple through both rural and urban food systems, affecting both affordability and access.

Drought serves as a destabilizing force for food systems in Nepal, resulting in fluctuations in food production from year to year. Between 1987 and 2017, frequent droughts occurred during critical agricultural seasons, leading to variability in harvest outcomes [6]. Notably, winter droughts have become more common in western Nepal due to both natural climatic variability and human-induced climate change [49], posing a threat to winter crops such as wheat and barley. Recent studies indicate intensified drought conditions since 2004, particularly in the Central and Eastern regions [50]. The Karnali Basin, for example, demonstrates significant spatial and temporal variability in drought occurrence [51]. This unpredictability in rainfall and soil moisture complicates agricultural planning, diminishes farmer confidence in planting decisions, and increases the risk of failed harvests. Projections suggest that the frequency of drought may continue to rise until mid-century (2020–2060) before stabilizing or decreasing later in the century [45], highlighting the urgent need for medium-term adaptation.

Drought also affects food utilization, the ability to absorb and metabolize nutrients by influencing crop diversity, water availability, and soil health. Reduced water availability and stressed crops can lead to lower-quality harvests, affecting both yield and nutritional content. Long-term aridity depletes soil moisture and organic matter, which diminishes the productivity of rain-fed agricultural systems that dominate much of Nepal's farmland. A study utilizing satellite-derived Vegetation Condition Index (VCI) data from 1982 to 2015 found significant spatial variations in the impacts of drought across Nepal, even though overall trends indicated slight improvement [52]. These spatial differences reveal that certain areas remain highly vulnerable, necessitating region-specific responses to ensure consistent nutritional outcomes.

Future projections are particularly alarming. Under high-emission scenarios such as SSP585 and RCP 8.5, drought severity and duration are expected to intensify [45,53], especially during already dry months like November. This situation heightens the threat of winter droughts, which could severely affect the nutritional intake of communities reliant on winter vegetables and grains. Furthermore, intensified drought conditions may limit access to clean water, compromise hygiene practices, and increase the risks of malnutrition and waterborne diseases, thereby undermining effective food utilization.

4.4. Synergistic Impacts on Crop Yields and Agricultural Productivity

The concurrent impact of floods and droughts significantly affects crop yields and agricultural productivity in Nepal. Floods cause immediate crop loss through submergence and soil erosion, while droughts decrease yields due to water stress and altered growing seasons. This combination creates a challenging environment for consistent agricultural production. For example, the frequent inundation of agricultural lands in the Terai region due to floods, followed by periods of drought, can severely disrupt agricultural cycles, leading to reduced productivity and increased food scarcity [54].

The erratic nature of these extreme events poses challenges for farmers in effectively planning and adjusting their agricultural practices. Research conducted in the West Rapti river basin revealed substantial fluctuations and high flood peaks. The study showed a strong correlation with the rainfall-flood regression formula (R^2 of 0.89) and highlighted severely affected areas such as Duduwa, Narainapur, and Rapti Sonari [40]. This variability, coupled with periods of drought, presents a multifaceted challenge for agricultural management.

Furthermore, floods and droughts can have lasting impacts on soil quality, with implications for agricultural productivity. Floods may result in soil erosion and the deposition of infertile sediments, while droughts can lead to soil degradation and reduced capacity to retain moisture. These changes in soil composition can significantly influence crop yields long after the extreme events have subsided. A study in the Marshyangdi Watershed indicates increasing temperature extremes and mixed trends in precipitation for the future period from 2014 to 2053. These trends could lead to increased flood magnitude and changes in riverine environments [29].

4.5. Food Security in Nepal: Historical, Present, and Future Scenarios

Nepal has been facing persistent challenges related to food insecurity and undernutrition, contributing to inadequate consumption and poor dietary diversity. The Nepal Living Standard Survey 2010/11 revealed that 25% of households were classified as food-poor, while 38% of the population consumed fewer calories than the minimum daily requirement for a healthy life [55]. According to a report published by the Nepal Planning Commission in 2013, 35% of people in Nepal experienced chronic food insecurity [56]. The Nepal Demographic and Health Survey 2016 further highlighted that around 52% of households experienced mild to severe food insecurity, with 4.6% facing moderate to severe hunger [57]. Regional disparities were apparent, with rural areas generally experiencing higher food insecurity compared to urban areas [58].

A study examining data from 1995 to 2011 found a substantial rise in the Simpson Index of Diversity, suggesting improved dietary diversity [59]. However, challenges persist, especially in remote areas where dietary diversity may be constrained due to ecological limitations [60]. In the 1990s, agriculture accounted for 44% of the GDP, but this share decreased to 34% by 2012–2013, reflecting a structural shift in the economy. The country experienced fluctuations in agricultural growth and food production, with yield growth often trailing behind population growth during this period [61]. The transition from reliance on self-produced food to market-based food consumption was relatively successful in the Terai region but faced challenges in the Middle Mountains and Trans-Himalaya areas [60]. This historical context provides a foundation for understanding the current food security situation in Nepal.

A 2024 report placed Nepal at the 68th position in the Global Hunger Index, with a score of 14.7 [25]. It revealed that approximately 5.7% of the population is undernourished, 24.8% of children under five are stunted, 7% are wasted, and 2.7% of children die before their fifth birthday. A similar pattern emerged in the Nepal Demographic and Health Survey Report 2022, which reported that 25%, 8%, and 19% of children under age five are stunted, wasted, and underweight, respectively [24]. The Nepal Living Standard Survey IV 2022–2023 showed that the food poverty line rose from NRs. 26,936 in 2010–2011 to NRs. 35,029 in 2022–2023, reflecting a significant increase in the cost of meeting basic caloric needs [23]. This upward shift underscores the growing financial burden on households to afford adequate nutrition as food prices have increased over the last decade.

Looking ahead, climate change is expected to have substantial impacts on food security in Nepal. Projected changes in temperature and precipitation, along with increased frequency and severity of droughts and floods, will likely affect crop productivity and the availability of food [62]. For example, in the Dudh Koshi catchment, yields of staple crops such as wheat, rice, and maize are expected to decline, particularly under high-emission scenarios [4]. The occurrence and severity of compounding environmental events are projected to rise, requiring more robust adaptation strategies to address food insecurity and malnutrition among vulnerable populations [30]. This underscores the urgent need for proactive measures to strengthen resilience and ensure sustainable food security in the face of climate change.

4.6. Socioeconomic Implications of Flood and Drought-induced Food Insecurity

Floods and droughts have a profound impact on rural livelihoods and food security throughout Nepal, resulting in significant socioeconomic consequences. In the western region, particularly Surkhet, the floods of 2014 caused widespread devastation to homes and incurred substantial economic losses. Research indicates that nearly 69% of households in this area have been affected by climate-induced disasters, suffering damages that include the destruction of homes, crops, livestock, and loss of income. Such losses intensify poverty levels and heighten the vulnerability of rural populations [27]. The repercussions for rural livelihoods are especially severe, as many households rely heavily on climate-sensitive sectors, particularly agriculture. A study [9] found that 41% of respondents in flood-affected regions experienced alterations in their economic activities and livelihood strategies, often resulting in increased seasonal or permanent migration and changes to their farming practices.

In drought-prone regions like Karnali, similar pressures are apparent. Climate extremes, including both droughts and floods, have prompted a gradual shift from traditional crops to more drought-resilient or market-driven alternatives [63]. While this transition has created some new income-generating opportunities, agriculture continues to be the primary livelihood for most households, leaving them particularly vulnerable to climatic variability. The impact on livelihoods is further exacerbated by the changing economic structure of Nepal. From the 1990s to 2012–2013, the agricultural sector's contribution to GDP fell from 44% to 34%, highlighting a broader economic transition that has increasingly exposed rural populations to climate risks without adequate safety nets or diversification of income sources [61].

The disruptions to livelihoods are closely tied to the volatility of food prices and the dynamics of market conditions. Climatic extremes, especially floods and droughts, can devastate standing crops, erode fertile land, and

disrupt transportation and market systems. Such impacts often lead to a decrease in agricultural output, which in turn drives up food prices, particularly in remote or poorly connected regions. A study [55] examined the factors influencing per capita food expenditure in Nepal, revealing that household characteristics, such as size, occupation, and location, significantly affect food security outcomes. Higher per capita food expenditure was positively correlated with improved food security, while larger household sizes and underdeveloped regions were associated with increased vulnerability. Disruptions in food access, driven by climatic shocks like droughts and floods, can worsen market instability and trigger spikes in food prices, further straining household budgets and access to nutritious food [30].

The impacts of flooding and drought are not distributed evenly across the population. Certain groups, particularly female-headed households and those residing in ecologically vulnerable areas, experience disproportionately severe effects. A study [61] emphasizes that household food security is significantly influenced by factors such as access to irrigation, ownership of land and livestock, and participation in off-farm employment. Female-headed households, which often have limited access to these critical resources, face a greater risk of food insecurity.

Geographical disparities further exacerbate this issue. According to a study [58], food insecurity is most pronounced in the mountain regions of Nepal, followed closely by the hill and Terai regions. These areas grapple with ongoing challenges resulting from difficult terrain, inadequate infrastructure, and heightened exposure to climate hazards. In the Karnali region, food insecurity induced by climate change disproportionately affects already vulnerable communities, highlighting the urgent need for targeted policies and interventions to assist at-risk populations [63].

Collectively, these insights underscore the multidimensional nature of food insecurity in Nepal, which is shaped by both climatic factors and underlying socioeconomic vulnerabilities. Floods and droughts not only compromise food production but also disrupt livelihoods, alter market dynamics, and intensify the risks faced by marginalized groups. Addressing these challenges necessitates the implementation of climate-resilient agricultural strategies, enhanced infrastructure and market access, and inclusive social protection systems that prioritize the most vulnerable populations.

4.7. Adaptation and Mitigation Strategies

Addressing the intricate impacts of floods and droughts on food security in Nepal necessitates the implementation of comprehensive adaptation and mitigation strategies that draw upon policy insights, both traditional and modern agricultural knowledge, infrastructure development, and ongoing research. Numerous studies have underscored the significance of both national-level policy frameworks and localized interventions in alleviating food insecurity driven by climate extremes.

Current policies and programs aim to confront food insecurity; however, notable gaps persist in terms of inclusivity and effectiveness. Research has highlighted the necessity of understanding food insecurity within vulnerable groups, particularly among female-headed households, and has recommended that future social policies be piloted in the districts experiencing the highest levels of food insecurity [57]. Additionally, the need for further qualitative research to explore the interactions between climate change, disaster vulnerability, and social policy outcomes is paramount. At the household level, adaptation strategies such as alterations in farming practices and shifts in economic activities are increasingly recognized as vital responses to climate stressors. These strategies may include cultivating high-altitude crops to cope with changing climatic conditions [62]. Nonetheless, to design effective interventions, future research must concentrate on assessing the actual impacts of current programs and identifying obstacles that impede their success.

Traditional agricultural knowledge, when combined with modern practices, offers significant potential for enhancing the resilience of food systems. The Asta-Ja Framework serves as a valuable perspective for promoting sustainable agriculture and smallholder mixed farming systems, addressing both food insecurity and environmental degradation [11]. Additionally, climate-induced shifts in temperature present an opportunity to cultivate crops at higher elevations. For instance, in the Himalayan region, rising temperatures have made it possible to grow crops in areas that were once deemed unsuitable, partially compensating for losses in lower-altitude farmland [4]. Concurrently, changes in labor dynamics, such as the increase in non-agricultural employment in districts like Kaski, have resulted in improved food access and enhanced well-being. Nevertheless, these transitions have also transformed traditional farming roles, underscoring the necessity for holistic planning that integrates both agricultural and non-agricultural livelihood strategies [64].

Looking ahead, several potential interventions have been identified to mitigate the adverse effects of floods and droughts on food security. For example, in the Karnali River Basin, the development of advanced flood

forecasting systems has proven essential for issuing timely warnings that protect agricultural activities and minimize damage [65]. Similarly, hydro-social analyses have highlighted the necessity for reliable, real-time hydrological data, with studies advocating for the validation of flood models and the exploration of long-term adaptation strategies [40]. Improved flood forecasting technologies, such as rainfall-runoff modeling in the West Rapti watershed, have demonstrated the potential to extend evacuation lead times and enhance early warning systems [66]. The use of the HEC-RAS model in the Chamelia River Basin has further illustrated how modeling tools can be utilized to assess hydraulic conditions and support effective flood management planning [33]. The widespread implementation of such technologies in other vulnerable river basins could significantly strengthen Nepal's resilience to food insecurity related to floods.

A comprehensive approach to addressing climate-related food insecurity necessitates significant investment in both technology and infrastructure. All four pillars of food security, availability, access, utilization, and stability, are profoundly affected by the quality of infrastructure, particularly in remote and mountainous regions. For instance, in areas like Upper Mustang, inadequate transportation networks lead to elevated food prices and limited availability, especially during seasonal disruptions [54]. Enhancing road connectivity, improving food storage systems, and optimizing supply chain logistics are crucial to stabilizing food markets and increasing access in hard-to-reach communities. Moreover, the successful application of modeling technologies, such as HEC-RAS in the Pathariya Khola study, highlights the importance of integrating technical tools into disaster preparedness and food security planning [43].

Despite recent advancements, significant knowledge gaps remain that impede comprehensive food security interventions. For instance, there is a noticeable deficiency of disaggregated and localized studies that examine the relationship between dietary quality and various socioeconomic and ecological factors [10]. This need is particularly pressing in remote areas like Upper Mustang, where the impacts of climate change on food systems are still insufficiently explored [60]. Additionally, socio-economic factors such as land tenure arrangements, household composition, and sharecropping practices continue to receive inadequate attention in the discourse surrounding food security. By addressing these gaps through targeted research, we can facilitate the development of more effective and context-specific policies and programs [64].

Altogether, a multi-faceted strategy that combines technological innovation, infrastructure development, traditional knowledge, inclusive policymaking, and localized research is essential for enhancing Nepal's resilience to food insecurity caused by floods and droughts. This approach should be adaptive, evidence-based, and inclusive, ensuring that the most vulnerable populations are not overlooked in the face of increasing climate risks.

4.8. Limitations and Research Gaps

A significant limitation commonly observed in studies related to floods, droughts, and food security in Nepal is the scarcity of reliable, high-resolution, and long-term data. Many flood-related analyses rely on global datasets or short-term local observations, typically spanning less than ten years, which diminishes the effectiveness of model calibration and flood hazard assessments [40,66,67]. These investigations tend to concentrate primarily on rainfall while frequently neglecting crucial factors such as land use changes, socio-economic conditions, and river bathymetry [33,35]. The lack of high-resolution topographic data and restricted access to precise elevation or bathymetric information have further hindered the reliability of flood modeling efforts. Additionally, insufficient station data, along with challenges like short spin-up times, poor rainfall estimation, and informal urban development practices, have adversely affected model accuracy and planning outcomes [41,65].

Drought-related research encounters similar challenges. Many studies are hindered by missing or incomplete records, uneven spatial coverage in meteorological networks, especially in mountainous areas and methodological limitations, such as an excessive reliance on the Thornthwaite method or the use of gridded datasets of questionable quality [50,68,69]. These factors diminish the ability to detect short-term drought events and introduce uncertainties in remote sensing-based indices. Furthermore, there is a significant lack of integration of anthropogenic factors, such as irrigation and land management practices, into drought assessments. In Nepal, real-time monitoring of droughts is largely absent, and national meteorological services are lacking robust systems for timely assessment and decision-making [44].

In the realm of food security research, methodological and data-related constraints remain significant. Many studies depend on outdated or secondary sources, such as the 2010/11 Nepal Living Standards Survey, which limits their relevance to current socio-economic and climatic contexts [6,10,30,70]. The use of cross-sectional designs and self-reported data introduces bias and constrains causal interpretation [61,71]. Additionally, various modeling approaches often rely on simplifying assumptions such as a singular soil layer or uniform nutrient availability that undermine the representativeness of the findings [4]. Furthermore, certain variables, such as migration income and

remittance flows, are frequently underreported or inconsistently measured, while the impact of federal governance structures on implementation has not been thoroughly examined [11,64].

Across these fields, there is a clear necessity for more comprehensive and updated datasets, especially those that capture fine-scale spatial and temporal variability. Researchers consistently advocate for the expansion of hydrometeorological stations, enhanced monitoring systems, and the integration of diverse variables, such as land use, socio-economic data, and topographical details, into modelling efforts [2,46]. Additionally, there is an urgent need for localized and regional studies that reflect ecological, climatic, and cultural diversity, particularly in underrepresented or vulnerable areas such as Nepal's mountainous regions and the Trans-Himalayan zone [45,62].

Research gaps highlight the necessity for field-based validation of models, the exploration of compound events and their cascading effects, and a more in-depth investigation into the socio-economic ramifications of floods and droughts, particularly for marginalized communities [27,36]. Longitudinal studies are crucial for gaining a better understanding of seasonal and long-term trends, particularly concerning crop-growing periods and evolving climate drivers [53,54]. Finally, there is a need for more nuanced approaches and refined indicators to assess vulnerability and resilience across the interconnected domains of climate risk and food security.

As we look to the future, it is essential to address existing knowledge gaps through a multidisciplinary approach that incorporates advancements in remote sensing, data assimilation, and climate modelling. Research efforts should prioritize the development of high-resolution, long-term datasets and integrated assessments that consider socio-ecological dynamics, particularly in regions sensitive to climate change. Notably, emerging trends such as the rising frequency of compound hydroclimatic extremes, shifts in agricultural practices, and demographic changes, including migration and urbanization, are poised to transform food security dynamics in Nepal. Consequently, the implementation of adaptive strategies, real-time monitoring systems, and community-centered research will be vital in informing evidence-based policy and fostering sustainable resilience planning.

5. Conclusions

This systematic literature review offers a comprehensive analysis of the interconnections between floods, droughts, and food security in Nepal. The study assessed 53 articles from an initial pool of 688 publications spanning from 1979 to 2024, providing a broad temporal perspective on these critical issues. The methodological analysis revealed that most of the studies (74%) employed quantitative methods, while 26% utilized a mixed approach that combined both quantitative and qualitative analyses. This underscores a reliance on data-driven research and highlights the necessity for integrated methodologies that encompass both quantitative trends and qualitative insights.

Descriptive analysis indicated a pronounced emphasis on flood-related studies, with a total of 186 articles, followed by research on food security (149 articles) and drought studies (39 articles). The exploration of intersections, such as the relationship between drought and agriculture (38 studies) and both drought and flood (6 studies), reflects an increasing awareness of these interconnected challenges. However, it is noteworthy that there were no studies linking floods to food security, highlighting a significant research gap.

Nepal's geographical and socio-economic context significantly contributes to its vulnerability to climate-related disasters. Its varied topography and reliance on monsoon-driven agriculture create conditions where floods and droughts pose severe threats to crop yields, soil quality, and overall agricultural productivity, thereby having lasting implications for food security. The combined effects of floods and droughts are particularly profound, disrupting all aspects of food security, availability, access, utilization, and stability. Floods result in immediate crop losses and damage to infrastructure, while droughts diminish yields and alter growing seasons. When these events occur together, they create substantial challenges for consistent agricultural production and food distribution, especially affecting rural livelihoods and income.

The review assessed current adaptation and mitigation strategies, highlighting a combination of policy interventions and innovative practices. Approaches such as high-altitude crop cultivation and the Asta-Ja Framework show promise, yet their scalability and effectiveness require further investigation. Key challenges include implementation difficulties across Nepal's diverse ecological regions and the need to adapt to shifting climate patterns. Additionally, the review pinpointed several research gaps and limitations, particularly concerning data availability, quality, and methodological approaches. Numerous studies have relied on specific indices or models that do not fully capture the complexity of the issues at hand. Addressing these gaps necessitates the collection of high-quality, comprehensive data and enhanced modelling techniques to better understand the impacts of hydroclimatic extremes on food security.

Looking ahead, the review stressed the importance of integrated studies that incorporate both environmental and socio-economic factors, robust early warning systems, and strategies designed to assist vulnerable populations.

Future agricultural planning should also consider climate scenarios to bolster resilience against hydroclimatic shocks. This review underscores the substantial impacts of floods and droughts on food security in Nepal while also noting the limited research that directly connects these climatic extremes. Both floods and droughts disrupt all facets of food security; however, comprehensive assessments are hindered by data and methodological challenges. Promising strategies, such as the Asta-Ja Framework, present avenues for adaptation but require further refinement. The review highlights the urgent need for integrated approaches, resilient systems, and climate-responsive strategies to mitigate the compounded risks posed by hydroclimatic extremes on food security in Nepal. Figure 6 summarizes the review in brief.

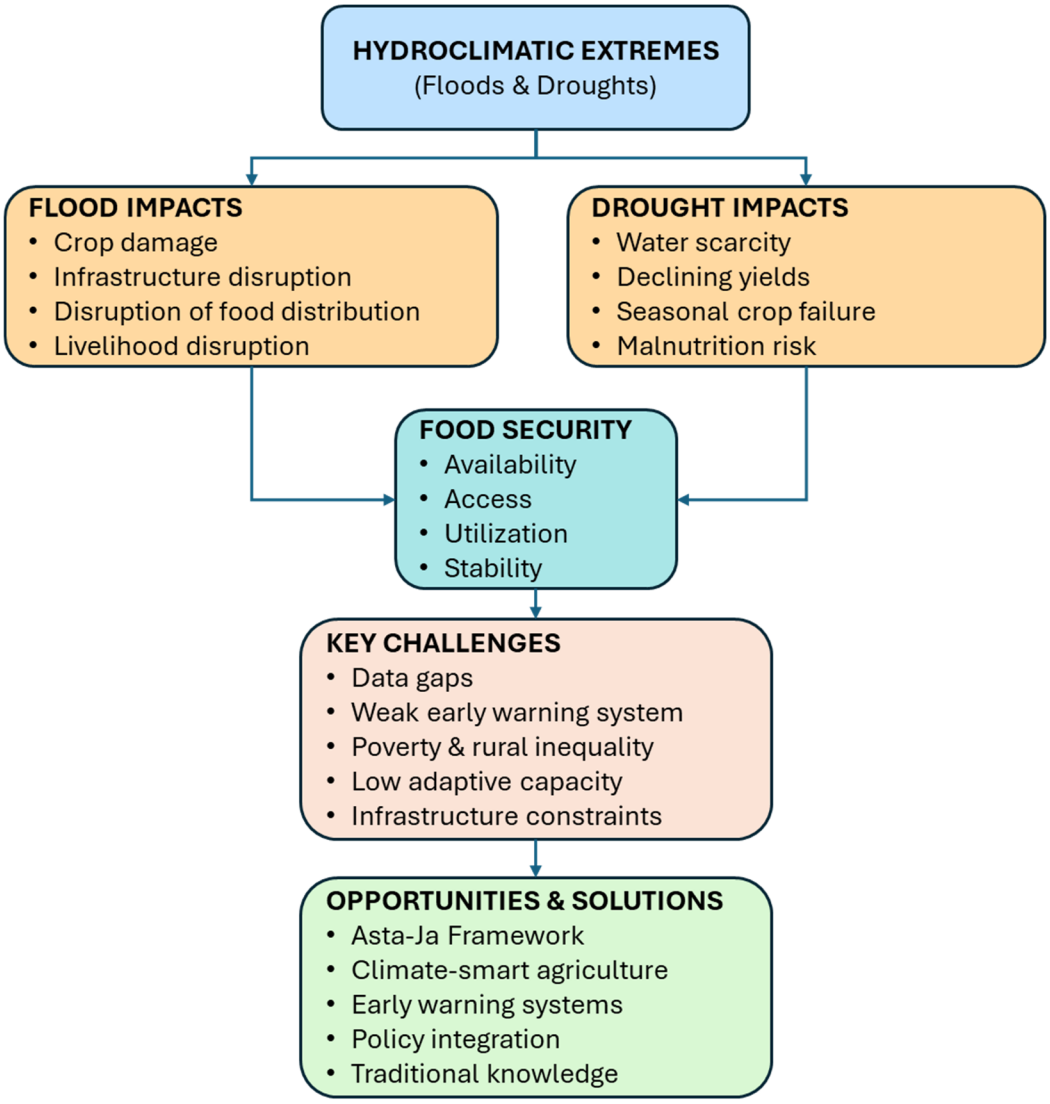

Figure 6. Schematic diagram summarizing the review.

Author Contributions

K.A.: Conceptualization, Methodology, Formal analysis, Writing—original draft. D.P.: Supervision, Writing—review & editing. D.A.: Supervision, Writing—review & editing. All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

The authors confirm that the data supporting the findings of this study are available within the article.

Acknowledgments

This research was supervised by Dhiraj Pradhananga, (Department of Meteorology, Tribhuvan University, Kathmandu, Nepal) and co-supervised by Deepak Aryal (Central Department of Hydrology and Meteorology, Tribhuvan University, Kathmandu, Nepal).

Conflicts of Interest

The authors of this review paper declare that they have no conflict of interest.

References

1. Shrestha, A.B.; Aryal, R. Climate change in Nepal and its impact on Himalayan glaciers. *Reg. Environ. Chang.* **2011**, *11*, 65–77. https://doi.org/10.1007/s10113-010-0174-9.
2. Shrestha, B.B. Assessment of Flood Hazard and Agriculture Damage Under Climate Change in the Bagmati River Basin of Nepal. *Int. J. Environ.* **2019**, *8*, 55–69. https://doi.org/10.3126/ije.v8i2.25508.
3. Shrestha, S.; Bajracharya, A.R.; Babel, M.S. Assessment of risks due to climate change for the Upper Tamakoshi Hydropower Project in Nepal. *Clim. Risk Manag.* **2016**, *14*, 27–41. https://doi.org/10.1016/j.crm.2016.08.002.
4. Bocchiola, D.; Brunetti, L.; Soncini, A.; et al. Impact of climate change on agricultural productivity and food security in the Himalayas: A case study in Nepal. *Agric. Syst.* **2019**, *171*, 113–125. https://doi.org/10.1016/j.agsy.2019.01.008.
5. Chemjong, B.; Yadav, K.C. Food Security in Nepal: A Review. *Rupantaran Multidiscip. J.* **2020**, *4*, 1–15. https://doi.org/10.3126/rupantaran.v4i1.34015.
6. Hamal, K.; Sharma, S.; Khadka, N.; et al. Assessment of drought impacts on crop yields across Nepal during 1987–2017. *Meteorol. Appl.* **2020**, *27*, e1950. https://doi.org/10.1002/met.1950.
7. Pandey, V.P.; Shrestha, D.; Adhikari, M. Characterizing natural drivers of water-induced disasters in a rain-fed watershed: Hydro-climatic extremes in the Extended East Rapti Watershed, Nepal. *J. Hydrol.* **2021**, *598*, 126383. https://doi.org/10.1016/j.jhydrol.2021.126383.
8. IPCC. *Climate Change 2022–Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, 1st ed.; Cambridge University Press: Cambridge, UK, 2022. https://doi.org/10.1017/9781009325844.
9. Poudel, D.D.; Funakawa, S.; Shinjo, H. Household Perceptions about the Impacts of Climate Change on Food Security in the Mountainous Region of Nepal. *Sustainability* **2017**, *9*, 641. https://doi.org/10.3390/su9040641.
10. Kumar, A.; Thapa, G.; Mishra, A.K.; et al. Assessing food and nutrition security in Nepal: Evidence from diet diversity and food expenditure patterns. *Food Secur.* **2020**, *12*, 327–354. https://doi.org/10.1007/s12571-019-01004-y.
11. Poudel, D.D. Asta-Ja Framework: A Peaceful Approach to Food, Water, Climate, and Environmental Security Coupled with Sustainable Economic Development and Social Inclusion in Nepal. *Strateg. Plan. Energy Environ.* **2023**, *39*, 1–20. https://doi.org/10.13052/spee1048-4236.391412.
12. Bohlinger, P.; Sorteberg, A. A comprehensive view on trends in extreme precipitation in Nepal and their spatial distribution. *Int. J. Climatol.* **2018**, *38*, 1833–1845. https://doi.org/10.1002/joc.5299.
13. DHM. *Observed Climate Trend Analysis in the Districts and Physiographic Regions of Nepal (1971–2014)*; Department of Hydrology and Meteorology: Kathmandu, Nepal, 2017. Available online: https://www.dhm.gov.np/climate-services/climate-publications (accessed on 4 November 2020).
14. Shrestha, D.; Sharma, S.; Hamal, K.; et al. Spatial Distribution of Extreme Precipitation Events and Its Trend in Nepal. *Appl. Ecol. Environ. Sci.* **2020**, *9*, 58–66. https://doi.org/10.12691/aees-9-1-8.
15. Hamal, K.; Sharma, S.; Talchabhadel, R.; et al. Trends in the Diurnal Temperature Range over the Southern Slope of Central Himalaya: Retrospective and Prospective Evaluation. *Atmosphere* **2021**, *12*, 1683. https://doi.org/10.3390/atmos12121683.
16. FAO. The State of Food Insecurity in the World 2006. Available online: https://www.fao.org/4/a0750e/a0750e00.htm (accessed on 26 October 2024).
17. FAO. FAO Strategy on Climate Change 2022–2031. Available online: https://openknowledge.fao.org/handle/20.500.14283/cc2274en (accessed on 20 June 2025).

18. FAO. The State of Food Insecurity in the World 2003. Available online: https://www.fao.org/4/j0083e/j0083e00.htm (accessed on 31 October 2024).
19. Shaw, D.J. World Food Summit, 1996. In *World Food Security: A History Since 1945*; Palgrave Macmillan: London, UK, 2007; pp. 347–360. https://doi.org/10.1057/9780230589780_35.
20. Shively, G.E.; Gars, J.; Sununtnasuk, C. A review of food security and human nutrition issues in Nepal. *Work. Pap.* **2011**. https://doi.org/10.22004/ag.econ.116190.
21. Karki, R.; Gurung, A. An Overview of Climate Change and Its Impact on Agriculture: A Review from Least Developing Country, Nepal. *Int. J. Environ.* **2012**, *2*, 1–9. https://doi.org/10.5923/j.ije.20120202.03.
22. Bocchiola, D. Agriculture and food security under climate change in Nepal. *Adv. Plants Agric. Res.* **2017**, *6*, 194–199. https://doi.org/10.15406/apar.2017.06.00237.
23. NSO. *Nepal Living Standards Survey 2022–2023*; National Statistics Office: Kathmandu, Nepal, 2024. Available online: https://nsonepal.gov.np/content/12061/12061-nepal-living-standards-survey/ (accessed on 18 October 2024).
24. NDHS. Nepal Demographic and Health Survey 2022-Key Indicators. Ministry of Health and Population, Nepal; New ERA; and ICF. 2022. Nepal Demographic and Health Survey 2022: Key Indicators Report. Kathmandu, Nepal: New Era, Nepal. Available online: http://www.newera.com.np/report/nepal-demographic-and-health-survey-2022-key-indicators/ (accessed on 18 October 2024).
25. Concern Worldwide; Welthungerhilfe; International Law of Peace and Armed Conflict (IFHV). Global Hunger Index 2024: How Gender Justice Can Advance Climate Resilience and Zero Hunger. Available online: https://www.globalhungerindex.org/ (accessed on 18 October 2024).
26. Moher, D.; Liberati, A.; Tetzlaff, J.; et al. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Med.* **2009**, *6*, e1000097. https://doi.org/10.1371/journal.pmed.1000097.
27. Bista, R.B. Examining Determinants of Household Vulnerability in Nepal: Descriptive Statistics Analysis of Flood Disasters. *Patan Pragya* **2022**, *11*, 139–152. https://doi.org/10.3126/pragya.v11i02.52111.
28. Awasthi, R.P.; Owen, J. Observed Climate Extreme in Nepal. *Geogr. Base* **2020**, *7*, 1–14. https://doi.org/10.3126/tgb.v7i0.34262.
29. Singh, R.; Pandey, V.P.; Kayastha, S.P. Hydro-climatic extremes in the Himalayan watersheds: A case of the Marshyangdi Watershed, Nepal. *Theor. Appl. Climatol.* **2021**, *143*, 131–158. https://doi.org/10.1007/s00704-020-03401-2.
30. Randell, H.; Jiang, C.; Liang, X.-Z.; et al. Food insecurity and compound environmental shocks in Nepal: Implications for a changing climate. *World Dev.* **2021**, *145*, 105511. https://doi.org/10.1016/j.worlddev.2021.105511.
31. Duwal, S.; Liu, D.; Pradhan, P.M. Flood susceptibility modeling of the Karnali river basin of Nepal using different machine learning approaches. *Geomat. Nat. Hazards Risk* **2023**, *14*, 2217321. https://doi.org/10.1080/19475705.2023.2217321.
32. World Bank. World Bank Climate Change Knowledge Portal. Available online: https://climateknowledgeportal.worldbank.org/ (accessed on 27 May 2024).
33. Adhikari, T.; Panthee, S. Application of Hydrodynamic (HEC–RAS) Model for Extreme Flood Analysis in Far-West Province: A case study of Chamelia River Basin, Darchula District, Nepal. *J. Geoinform. Nepal* **2020**, *19*, 9–15. https://doi.org/10.3126/njg.v19i1.50961.
34. Yogacharya, K.; Gautam, D. Floods in Nepal: Genesis, Magnitude, Frequency and Consequences. *ResearchGate* **2008**. https://doi.org/10.13140/RG.2.1.2376.8489.
35. Aryal, D.; Wang, L.; Adhikari, T.R.; et al. A Model-Based Flood Hazard Mapping on the Southern Slope of Himalaya. *Water* **2020**, *12*, 540. https://doi.org/10.3390/w12020540.
36. Subedi, B.; Jha, P.C.; Gautam, N.; et al. Comparative Study of Flood and Long-term Mean Monthly Flow Estimation Approaches: Case Studies of Six Basins in Nepal. *Geogr. Base* **2022**, *9*, 15–38. https://doi.org/10.3126/tgb.v9i1.55425.
37. Chhetri, T.B.; Dhital, Y.P.; Tandong, Y.; et al. Observations of heavy rainfall and extreme flood events over Banke-Bardiya districts of Nepal in 2016–2017. *Prog. Disaster Sci.* **2020**, *6*, 100074. https://doi.org/10.1016/j.pdisas.2020.100074.
38. Bista, R. The Impact of Vulnerability and Income distribution on Inequality and Poverty: Analysis of Flood and landslides in Vulnerable Locations of Nepal. *Forum Soc. Econ.* **2020**, 1–12.
39. Rai, C.M.; Chhetri, R.; Dahal, B.P.; et al. Analysis of rainfall and return periods to assess flood risks in hilly areas of Nepal. *J. Geom.* **2020**, *9*, 1–12.
40. Devkota, R.; Bhattarai, U.; Devkota, L.; et al. Assessing the past and adapting to future floods: A hydro-social analysis. *Clim. Chang.* **2020**, *163*, 1065–1082. https://doi.org/10.1007/s10584-020-02909-w.
41. Rijal, S.; Rimal, B.; Sloan, S. Flood Hazard Mapping of a Rapidly Urbanizing City in the Foothills (Birendranagar, Surkhet) of Nepal. *Land* **2018**, *7*, 60. https://doi.org/10.3390/land7020060.
42. Acharya, B.; Joshi, B. Flood frequency analysis for an ungauged Himalayan river basin using different methods: A case

study of Modi Khola, Parbat, Nepal. *Meteorol. Hydrol. Water Manag.* **2020**, *8*, 46–51. https://doi.org/10.26491/mhwm/131092.

43. Upadhyaya, B.R.; Gajurel, A.P.; Thapa, P.B.; et al. Flood hazard modelling using HEC-RAS in the Pathariya Khola, Far-western Nepal. *J. Nepal Geol. Soc.* **2023**, *66*, 119–130. https://doi.org/10.3126/jngs.v66i01.57957.
44. Bagale, D.; Sigdel, M.; Aryal, D. Drought Monitoring over Nepal for the Last Four Decades and Its Connection with Southern Oscillation Index. *Water* **2021**, *13*, 3411. https://doi.org/10.3390/w13233411.
45. Sharma, S.; Hamal, K.; Khadka, N.; et al. Projected Drought Conditions over Southern Slope of the Central Himalaya Using CMIP6 Models. *Earth Syst. Environ.* **2021**, *5*, 849–859. https://doi.org/10.1007/s41748-021-00254-1.
46. Aryal, A.; Maharjan, M.; Talchabhadel, R.; et al. Characterizing Meteorological Droughts in Nepal: A Comparative Analysis of Standardized Precipitation Index and Rainfall Anomaly Index. *Earth* **2022**, *3*, 409–432. https://doi.org/10.3390/earth3010025.
47. Kafle, H. Spatial and Temporal Variation of Drought in Far and Mid Western Regions of Nepal: Time Series Analysis *(*1982–2012). *Nepal J. Sci. Technol.* **2015**, *15*, 31–40. https://doi.org/10.3126/njst.v15i2.12118.
48. Lobell, D.B.; Field, C.B. Global scale climate–crop yield relationships and the impacts of recent warming. *Environ. Res. Lett.* **2007**, *2*, 014002. https://doi.org/10.1088/1748-9326/2/1/014002.
49. Wang, S.Y.; Yoon, J.-H.; Gillies, R.; et al. What Caused the Winter Drought in Western Nepal during Recent Years? *J. Clim.* **2013**, *26*, 8241–8256. https://doi.org/10.1175/JCLI-D-12-00800.1.
50. Hamal, K.; Sharma, S.; Pokharel, B.; et al. Changing pattern of drought in Nepal and associated atmospheric circulation. *Atmos. Res.* **2021**, *262*, 105798. https://doi.org/10.1016/j.atmosres.2021.105798.
51. Khatiwada, K.R.; Pandey, V.P. Characterization of hydro-meteorological drought in Nepal Himalaya: A case of Karnali River Basin. *Weather Clim. Extrem.* **2019**, *26*, 100239. https://doi.org/10.1016/j.wace.2019.100239.
52. Baniya, B.; Tang, Q.; Xu, X.; et al. Spatial and Temporal Variation of Drought Based on Satellite Derived Vegetation Condition Index in Nepal from 1982–2015. *Sensors* **2019**, *19*, 430. https://doi.org/10.3390/s19020430.
53. Dahal, P.; Shrestha, M.L.; Panthi, J.; et al. Modeling the future impacts of climate change on water availability in the Karnali River Basin of Nepal Himalaya. *Environ. Res.* **2020**, *185*, 109430. https://doi.org/10.1016/j.envres.2020.109430.
54. Pandey, R.; Bardsley, D.K. An application of the Household Food Insecurity Access Scale to assess food security in rural communities of Nepal. Asia Pac. *Policy Stud.* **2019**, *6*, 130–150. https://doi.org/10.1002/app5.270.
55. Regmi, H.R.; Rijal, K.; Joshi, G.; et al. Assessing Determinants of the Per Capita Food Expenditure from Household Expenditure: A Prospect of Food Security in Nepal. *Int. J. Sci. Basic Appl. Res.* **2019**, *48*, 116–123.
56. NPC. Nepal Thematic Report on Food Security and Nutrition 2013. Available online: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://dohs.gov.np/wp-content/uploads/chd/Nutrition/Food_and_Nutrition_Thematic_Report_2013.pdf (accessed on 7 December 2024).
57. KC, J.; Bist, A.; Rawal, D.; et al. Hunger Level and Factors Associated with Household Food Security in Nepal: Analysis of Finding from Nepal Demographic and Health Survey 2016. *J. Food Secur.* **2016**, *6*, 44–53.
58. Bhandari, P. Regional Variation in Food Security in Nepal. *Dhaulagiri J. Sociol. Anthropol.* **2018**, *12*, 1–10. https://doi.org/10.3126/dsaj.v12i0.22174.
59. Kumar, A.; Kumar, P.; Joshi, P.K. Food Consumption Pattern and Dietary Diversity in Nepal: Implications for Nutrition Security. *Indian J. Hum. Dev.* **2016**, *10*, 397–413. https://doi.org/10.1177/0973703017698899.
60. Pandey, R. The State of Food (In)Security in the Trans-Himalaya, Upper-Mustang, Nepal. *Dhaulagiri J. Sociol. Anthropol.* **2016**, *10*, 92–122. https://doi.org/10.3126/dsaj.v10i0.15882.
61. Joshi, G.R. Household food security: Trends and determinants in mountainous districts of Nepal. *Future Food: J. Food Agric. Soc.* **2017**, *5*, 42–55.
62. Neupane, N.; Paudel, S.; Sapkota, R.; et al. Enhancing the resilience of food production systems for food and nutritional security under climate change in Nepal. *Front. Sustain. Food Syst.* **2022**, *6*, 968998. https://doi.org/10.3389/fsufs.2022.968998.
63. Thapa, S.; Hussain, A. Climate change and high-altitude food security: A small-scale study from the Karnali region in Nepal. *Clim. Dev.* **2021**, *13*, 713–724. https://doi.org/10.1080/17565529.2020.1855099.
64. Gartaula, H.; Patel, K.; Johnson, D.; et al. From food security to food wellbeing: Examining food security through the lens of food wellbeing in Nepal's rapidly changing agrarian landscape. *Agric. Hum. Values* **2017**, *34*, 573–589. https://doi.org/10.1007/s10460-016-9740-1.
65. Gautam, D.K.; Dugar, S. Improving Flood Forecasting in Karnali River Basin of Nepal Using Rainfall—Runoff Model and Complementary Error Model. *IDRiM J.* **2020**, *9*, 21–48. Available online: https://www.idrimjournal.com/article/11832-improving-flood-forecasting-in-karnali-river-basin-of-nepal-using-rainfall-runoff-model-and-complementary-error-model/stats/all/pageviews (accessed on 31 July 2024).
66. Talchabhadel, R.; Shakya, N.M.; Dahal, V.; et al. Rainfall runoff modelling for flood forecasting (a case study on west rapti watershed). *J. Flood Eng.* **2015**, *6*, 53–61.

67. Bajracharya, S.R.; Shrestha, M.S.; Shrestha, A.B. Assessment of high-resolution satellite rainfall estimation products in a streamflow model for flood prediction in the Bagmati basin, Nepal. *J. Flood Risk Manag.* **2017**, *10*, 5–16. https://doi.org/10.1111/jfr3.12133.
68. Sigdel, M.; Ikeda, M. Spatial and Temporal Analysis of Drought in Nepal using Standardized Precipitation Index and its Relationship with Climate Indices. *J. Hydrol. Meteorol.* **2010**, *7*, 59–74. https://doi.org/10.3126/jhm.v7i1.5617.
69. Bista, N.; Mahat, D.; Manandhar, S.; et al. Analyzing Trend and Pattern of Agricultural Drought: A Case Study of Karnali and Sudurpashchim Provinces. *J. Geoinform. Nepal* **2021**, *20*, 1–8. https://doi.org/10.3126/njg.v20i1.39470.
70. Khadka, D.; Pathak, D. Climate change projection for the marsyangdi river basin, Nepal using statistical downscaling of GCM and its implications in geodisasters. *Geoenviron. Disasters* **2016**, *3*, 13. https://doi.org/10.1186/s40677-016-0050-0.
71. Maharjan, K.L.; Joshi, N.P. Determinants of household food security in Nepal: A binary logistic regression analysis. *J. Mt. Sci.* **2011**, *8*, 403–413. https://doi.org/10.1007/s11629-011-2001-2.