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A SMARTPHONE APP FOR THE RISK AND VULNERABILITY ASSESSMENT OF INDIAN AGRICULTURE TO CLIMATE CHANGE

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ABSTRACT
Food security and agricultural sustainability face major challenges due to climate change. Climate change has far-reaching effects on agriculture and climate projections have consequences for the long-term viability of agricultural output and the livelihoods of those who rely on it. Given the regional variability in both climate and climate change, not all regions are hit equally by this phenomenon, and the adaptation capacity to climate-related shocks also differs among regions. Building resilience in agriculture and farmers' livelihoods requires a well–thought-out and multi-pronged strategy involving adequate financial and human resources. To expand and focus on effective adaptation strategies, it is crucial to identify locations vulnerable to climate change. Our identification process is an a relative risk and vulnerability analysis across districts that are development and administrative units in India. Access to technology and information is one of the most important factors in empowering smallholders to make decisions. Specifically, farmers and other relevant agencies must have access to timely and relevant information to anticipate impending dangers. Through information and communication technology (ICT) initiatives, particularly the use of mobile phone-based communication platforms, farmers, extension workers, and policymakers can more effectively collaborate to provide advice on how to deal with these dangers. Using data from a risk assessment for climate change at the district level, a smartphone app called "Risk and Vulnerability Assessment of Indian Agriculture to Climate Change" was built. This Android app provides users with data on many factors and indicators of climate change risk in specific areas. The app is expected to enable policymakers, researchers, and extension workers to gain access to the data that they need to design adaptation initiatives and investments.

KEYWORDS: mobile app, ICT, risk, vulnerability, policymakers

1.INTRODUCTION

Increased agricultural productivity in small farms is an essential factor in economic growth and poverty reduction in developing nations like India (Mellor and Malik 2016). However, smallholder farmers are often confronted with a number of obstacles, such as erratic weather, market hazards, and a lack of access to information, technologies, and financial services, resulting in low productivity and low rates of market involvement (Key et al. 2000). An enormous adoption gap exists among Indian farmers, with 60% believed to have no access to any knowledge on modern agricultural technologies (National Sample Survey Organisation 2005). Therefore, addressing the main information and market access barriers that small holder farmers face is a critical policy concern for supporting rural development and reducing poverty.

Agricultural extension services are often the most common tool in developing nations for public sector support for knowledge dissemination and innovation in the small farm sector (Takahashi *et al*. 2020). Farmers' knowledge of best practices has traditionally been disseminated through extension agents' efforts to either educate them directly or to work with select "model farmers" (Taylor and Bhasme 2018). Traditional extension methods have not been successful because they either do not reach enough farmers or provide them with knowledge that is not adapted to their specific circumstances (Pallavi and Matin 2021).

Because information communication technologies (ICTs) can supplement traditional extension systems for the distribution of a "Knowledge Resource" to millions of Indian farmers, their incorporation into agricultural extensions is expected to be useful in providing a much-needed boost to the agricultural industry (Saravanan 2010).

2.ICT in Agriculture

The widespread implementation of ICT has revolutionized the way businesses all over the world operate, increasing output per employee. "One sector of the world economy that is seeing massive ICT implementation is agriculture. ICT applications offer the potential to detect and develop solutions for agricultural problems, including protracted droughts, insect and disease outbreaks, seasonality, regional dispersion of farming, high transaction costs, and information asymmetry (Anh *et al*. 2019). ICT also shows promise in enabling farmers to

obtain information quickly. In recent years, ICTs have become one of the primary driving tools used by farmers to manage the basic factors of agricultural production (land, labor, capital, and soil) (Daum 2022). They can be a game-changer in aiding not only in the management and marketing of production, but also in the management of land and its natural resources (Da Cruz *et al*. 2015), as well as the enhancement of production chains (Csótó 2015). The use of ICT to foster growth in the agricultural sector is called e-agriculture (Arroqui *et al*. 2012). E-agriculture needs access to the Internet and various forms of ICT, such as mobile communication technologies (MCT), geographic information systems (GIS), and remote sensing (RS), to operate. It is possible that m-agriculture, a sub-concept of e-agriculture, will be able to incorporate remote data collection from automated weather stations (AWS) or systems and sensors used in location-based monitoring (Brugger 2011).
Modern media and communication technologies are used as tools to spread knowledge. As evidenced by interviews and focus groups held at various locations, producers' information needs vary widely throughout the growing season. Regardless of location or type of crop grown, farmers all required the same basic types of data (Mittal *et al*. 2010). Figure 1 shows the bare minimum of the data required by farmers. The rate at which farmers can communicate and share these data have been accelerated by recent developments in the realm of digital platforms, such as e-commerce, agro-advisory apps, big data, computational power, and satellite systems like RS (Wolfert *et al*. 2017). Regardless of where they live, farmers need access to data on soil composition, seed varieties, pesticide needs during the crop life cycle, fertilizer options, crop diseases, and sales (Mittal *et al*. 2010). Knowledge, context, and market intelligence comprise the three primary levels at which the data are broken down.

Figure 1. Information needed from farmers through the agricultural cycle (Adapted from Reference Mittal, 2010)

The questions posed by farmers at each stage that must be addressed for better crop production.Small farmers identified weather, plant protection (disease/pest management), seed information, and market prices as their top four information needs. They found that mobile telephony was an effective replacement for traditional information delivery channels (Overa 2006).

2.1.Smartphone Use

Smartphones and mobile phones with Internet access are the most popular ICT devices worldwide. In 2019, there were 3.2 billion smartphone users worldwide, and this number is expected to rise to 3.8 billion by 2021 (Oberlo 2019). The percentage of smartphone users in developing nations was found to be the greatest in the globe (O'Dea 2020). Figures 2 and 3 display the annual and global smart phone user bases in the millions and broken down by nationality. In 2021, the number of smartphone users was 6.259 billion and it is likely to reach 7.6 billion in 2027 (Figure 3) (Statista 2022).
From a mere 4% in 2007, nearly half of India's total population of 1.37 billion people will have access to the internet by 2021, when the country's penetration rate will reach approximately 47%. By September 2021, there were 118.9 crore telephone connections, up from 93 crore in March 2014—an increase of 28% (ITU Publications 2021). In September 2021/22, the number of mobile connections in India reached 1165.97 million (ITU Publications 2021).
Among other information and communication technologies, the use of mobile phones has increased in the agricultural sector. With the increasing expansion of ICTs across all industries, new ICT applications have been developed to improve the access of farmers, extension agents, and other stakeholders to timely data (Nyarko and Kozári 2021). The technical advantages of smartphones, such as touch displays, easy readability, high-resolution cameras, and a global positioning system that facilitates navigation services, have led to their widespread use as a primary means of communication.

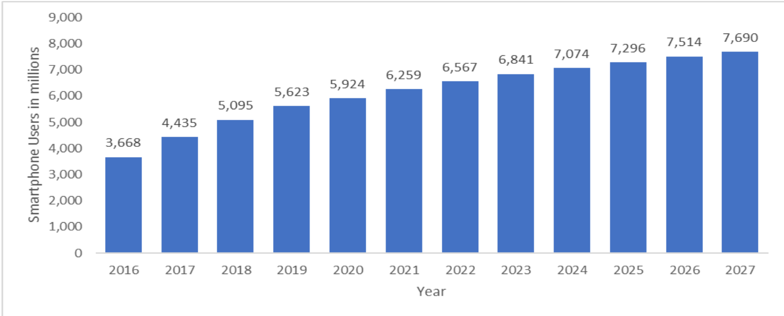

Figure 2. Number of smartphone users worldwide

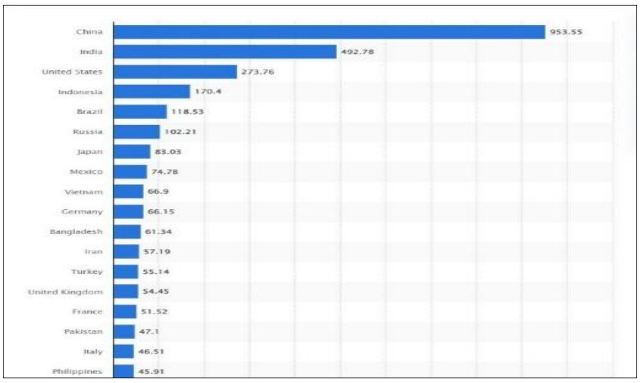

Figure 3. Number of smartphone users countrywide (Source: Stata, 2022)

2.3.Mobile Applications

According to research conducted by Jain and Sanhi (2016) of the Boston Consulting Group , new internet users are likely to reside in rural areas. Customers will increasingly use their mobile devices to surf the web as the number of public Wi-Fi hotspots increases and the cost of phones drops (Jain and Sanhi 2016). The proliferation of mobile apps is a direct result of the widespread popularity of smartphones (Qiang *et al*. 2012). Opportunities for mobile-based application development have emerged in agricultural systems because of the proliferation of mobile technology, which allows for the instantaneous dissemination of data on a wide range of topics. Farmers and extension agents can thus take advantage of the growing popularity of mobile-based technologies to improve collaboration and close the knowledge gap. Evidence from several studies demonstrates that farmers benefit from increased access to information, owing to the widespread adoption of mobile phones in the agricultural sector (Bhavnani *et al*. 2008). Farmers and other stakeholders can use their mobile devices to access a variety of resources, including market prices and forecasts, information on pests and diseases, and advice on how best to use seeds and fertilizers.

Research conducted worldwide has revealed that farmers' access to mobile phones may help them manage the effects of agricultural risks (Mittal *et al*. 2010; Aker 2008, 2010; World Bank 2011). It is therefore necessary to find ways of meeting the information demands of small and marginal farmers and ensure that the data farmers receive are location-specific and applicable to a wide range of farming situations. The agro-advice model delivered via mobile phones must also be long-lasting (Mittal 2012). Given the proliferation of mobile devices in the Indian market over the past decade (Cranston and Painting 2010), there is a promising window of opportunity for mobile-based smart applications to provide time-sensitive data to a wide range of interested parties, including farmers, extension workers, merchants, and manufacturers (Woodill and Udell 2012).

A mobile app is a piece of software installed on a portable device such as a smartphone or tablet. The app can be downloaded onto a device by visiting its dedicated webpage or third-party app store. There are two main categories of apps: static apps and those that update in real time, such as apps providing market prices and weather updates. To access the app's backend database, which is hosted on a distant server, the user must be within range of the device network. Apps are widely used among people with mobile devices all across the world. The rising rate of app downloads is a good indicator of the apps' widespread acceptance. Since 2016, global mobile app downloads have increased annually and reached 204 billion in 2019 (Figure 4). From 140.7 billion app downloads in 2016 to 230 billion app downloads in 2021, app downloads have had a growth rate of over 63%. This pattern will keep on repeating itself in the years to come.

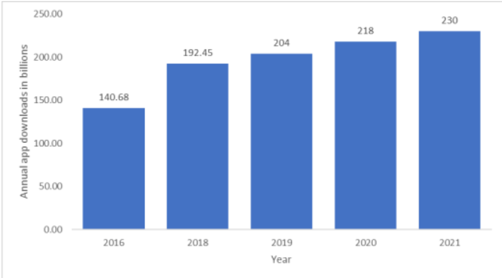

Figure 4. Annual app downloads in billions
(Source: https://www.statista.com/statistics/271644/worldwide-free-and-paid-mobile-app-store-downloads/; https://www.emizentech.com/blog/key-mobile-app-statistics.html)

Apps for Android and iOS devices can be downloaded via the Google Play Store and Apple App Store, respectively, both of which account for 98% of all app downloads on mobile devices. The share of downloads from both platforms increased between 2019 and 2020. In 2021, Apple's App Store saw 32.3 billion downloads, whereas Google Play reached over 110 billion. Google Play witnessed a 31% increase in downloads, whereas the Apple App Store witnessed a more modest 2.5% increase, suggesting that the Google Play Store is more popular and expanding faster than its rivals. During the first quarter of 2022, Google Play had the most number of available apps, with 3.3 million options for Android users, while the App Store came in second with almost 2.1 million iOS apps. App stores such as Apple and Google are notorious for removing poor-quality content on a regular basis; therefore, the actual number of apps may change, but overall, the download trend continues to move upward (Figure 5).

Figure 5. Major Apps Play Stores in 2021 (Source: Qiang et al. [2012])

Different people use various mobile apps across different devices, each with a unique operating system. It is now possible to access digital content using a wide range of devices. Numerous computer types are available to the public. Smartwatches, TVs, cars, and even homes can be used to access the Internet and its plethora of applications and media. Android and iOS devices are the most popular applications. Therefore, native distribution mechanisms such as the Google Play Store and Apple App Store make mobile apps easily accessible to users.

The number of downloads and ratings offered by users indicate how popular an app is. The logo, title, source description, country of origin, geographic coverage, target group, downloads, and ratings are all aspects of an app. The nature of the mobile device used to access an application also affects its utilization. Today, everyone has access to a variety of computing devices, including smartphones, tablets, desktops, and laptops. The new generation of smartphones and tablets is used to access mobile applications. Globally, smartphones have twice as many users as tablets (2.7 billion vs. 1.35 billion). However, it is important to note that presence on a device does not necessarily indicate that the app is being utilized. According to previous studies, people download apps, but do not use them. Data shows that 25% of programs are used only once after download and never opened again (Emizentech 2022).

The creation and use of mobile apps are on the rise in agriculture and related industries. In daily farming operations, farmers require up-to-date information and are interested in two-way communication. Therefore, it is important to have access to dynamic mobile apps. Although an active Internet connection is not needed to use the program in static mode, it is required to download the app. The Indian government has released many agriculture-related mobile apps for the benefit of farmers and other stakeholders. These apps can be found and downloaded from the Kisan app store.

2.4.Mobile Applications on Climate Change Risk

Growing climate variability and a shifting climate are two of the most significant risks to sustainable agriculture and livelihoods, calling for immediate and coordinated responses from a wide range of organizations and stakeholders. While both adaptation and mitigation are necessary responses to climate change, adaptation is more pressing for developing nations such as India. The first step in adaptation planning is to identify areas of vulnerability and risk". Dealing with climate change requires planned adaptation. As adaptation benefits are local in nature, as opposed to mitigation, spatially disaggregated information on extent and factors associated with risk is essential for making adaptation planning and implementation more effective.

An attempt was made to provide such information through a risk and vulnerability assessment of Indian agriculture to climate change (Rama *et al*. 2019) that assessed districts for their relative climate change risk. This mobile app was developed to make this information easily accessible to those involved in adaptation planning and implementation at national, state, and district levels. Farmers can take adaptation measures only if they have access to and are made aware of the relevant data; therefore, data generation and dissemination are prerequisites. The relative levels and driving variables of vulnerability and risk should be detailed in a district-level evaluation of climate change risks and vulnerability (Rama *et al*. 2019). Stakeholders interested in adaptation implementation and agricultural development can now access these valuable district-specific data through smartphone applications. Based on the developed atlas (Rama *et al*. 2019), an attempt was made to develop a mobile app called “Risk and Vulnerability Assessment of Indian Agriculture to Climate Change” to disseminate information on climate change risk, as well as on various components and indicators for the districts of choice.

3.MATERIALS AND METHODS

3.1.Creation of knowledge base

The Intergovernmental Panel on Assessment Report 5 framework and definitions were followed (Rama et al. 2019) to assess the risk and vulnerability to climate change. The risk index was calculated as the weighted sum of the exposure, vulnerability, and hazard indices, which were the sums of the weighted sums of the pertinent variables, allowing for the identification of districts with varied degrees of risk. This atlas outlines the entire procedure and lists the indicators used to compute the indices of the risk components (Rama *et al*. 2019). Climate forecasts from a selection of CMIP-5 global climate models capture future climate hazards in terms of changes in agriculturally relevant indicators from baseline estimates (1976–2005). Indicators were calculated using RCP 4.5 forecasts for the years 2020–2049. An Android-based mobile app was developed using Android Studio (Rama *et al*. 2019) as a knowledge base.

3.2.Mobile App Development

The “Risk and Vulnerability Assessment of Indian Agriculture to Climate Change” mobile app was developed to convey information on climate change risk, along with its numerous components and indicators for districts, to policymakers, researchers, and farmers. It was developed using Studio Preview 3.4, and the application database was designed using SQlite. The primary users of the smartphone app agencies concerned with agricultural development in the district, state, and national federal governments with an interest in agricultural progress were identified as the primary users of this smartphone app. The app development process is depicted in Figure 6.

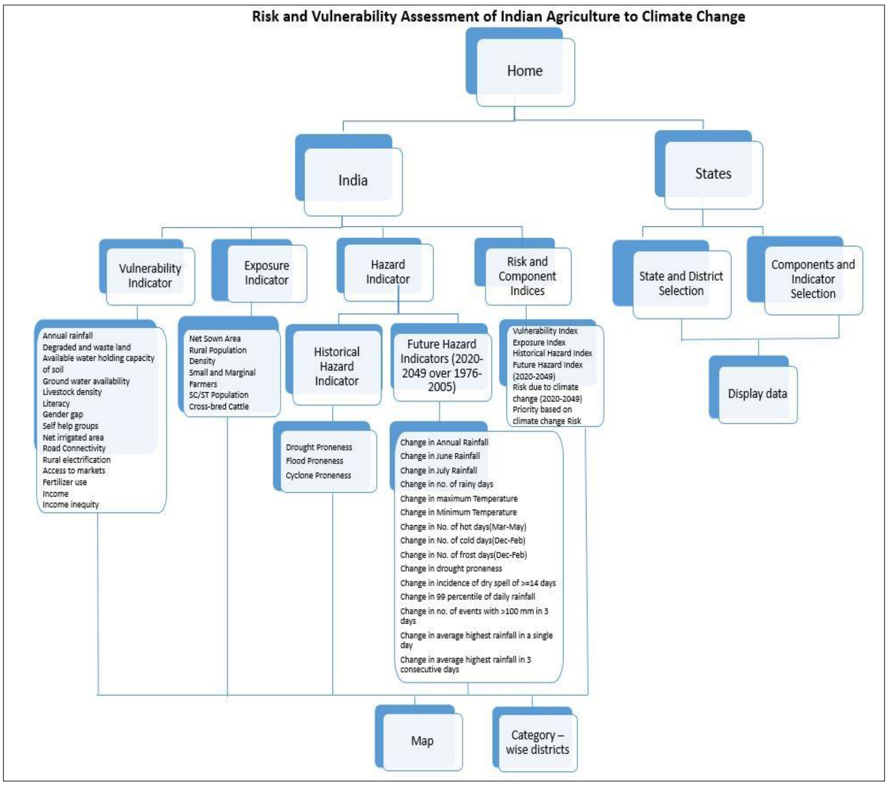

Figure 6. Stages of app development

4.RESULTS

4.1.Mobile App Development Life Cycle

We followed the standard procedure for creating apps for mobile devices. The mobile app was developed by following the mobile app development life cycle (MADLC) (CRIDA 2018). It is essential to provide original features and functionality while creating a mobile app. As long as we stick to the development steps from the beginning of mobile app development, we should be able to achieve our goals. MADLC is a mobile-centric version of the more familiar “Software Development Lifecycle” (SDLC). There are several stages involved in mobile app development, as shown in Figure 6. The MADLC is illustrated in Figure 7.

Figure 7. Mobile app development life cycle (Source: https://www.credencys.com/blog/mobile-app-development-lifecycle/)

4.2.1. Planning and Research

During the preliminary stages of creating a mobile app, developers focus on gathering information and making plans. In terms of the long-term impact, the foundation created at this stage determines the success or failure of an application. During this stage, we brainstormed and conducted extensive research using a custom-built questionnaire to learn about the app’s target platform and its users. We conducted an in-depth study to identify any features missing from the app’s development and incorporated these findings into the final requirement analysis document. We then developed the app’s goals, intended users, desired platforms, preferred app development languages, and frameworks.

4.2.2. Assessment of Technical Feasibility

Following a thorough examination of these requirements, we established Android as an appropriate platform for this project. The data storage backend was then completed and its viability for use in the development process was evaluated.

4.2.3. Wireframe and Prototype

At this stage in the app development, we now have a solid notion of the functions that must be included. We used this information to create a detailed prototype of the app to help visualize how it works. Wireframing is the process of creating an approximate sketch of an app. In addition, we constructed a storyboard or functional prototype that helps us see how the various screens of the app are related to one another.

4.2.4. Designing, Developing, and Testing the App

After developing the prototype, we completed the app design and considered the following in doing so:

- Maintained a balance between user interface and the content
- Ensure to integrate the features while designing the app
- Maintain clarity and consistency in the flow
- Create an interactive User Interface (UI)

A backend database was then developed. Subsequently, different user interfaces were integrated and linked to the database. During testing, we checked for technical flaws or bugs by cross-checking the developed app design and original planning design documents to see if the requirements were met successfully. During this phase, any flaws were immediately corrected.

4.2.5. Deployment and App Launch

After rigorous testing for technical problems and defects, the software was released. The application was deployed on the server and checked for compliance with the data leakage security criteria. Extreme measures were taken to ensure the safety of the database. Once every aspect of the app was ready, it was uploaded and registered on Google’s Play Store.

4.2.6 App Enhancement

After an application is released, it must undergo ongoing updates and enhancements. It is also important to constantly improve user experience by adding new features. To that end, we will amass user comments and, where necessary, fix or add to the app based on the data gathered.

5. DISCUSSION

The system design documents the planned features and hardware requirements of the app, as determined by the requirements defined in the requirement analysis phase. The proposed enhancements were implemented in subsequent phases of the project. In the design process, choices were made based on the computer software,

hardware, and programming language. The features and functions of the ap were meticulously crafted to provide users with the most intuitive experience. To guarantee the proper functioning of the app, each step was examined and approved before implementation. Android Studio is the preferred IDE (integrated development environment) as it simplifies the creation of apps with greater functionality and depth. A PHP script was used to access the database and to encode the data in JSON. This program gathers information from the database, stores it in the JSON format, and presents it to the user. Some data are also written in the app's XML format.
The database stores the data in the form of maps and tables for each indication. The user can also see the data for the entire state or for all states. Users have the option to view data for only India or state-wide on the app's homepage after installation. The state, district, and indication were selected using drop-down menus from a state-wide view. Selecting the India-specific option provides users with a graphical representation of the data according to their chosen indicators. The app received copyright
Figure 8. Indicator wise information in the map form when the option "India" is selected

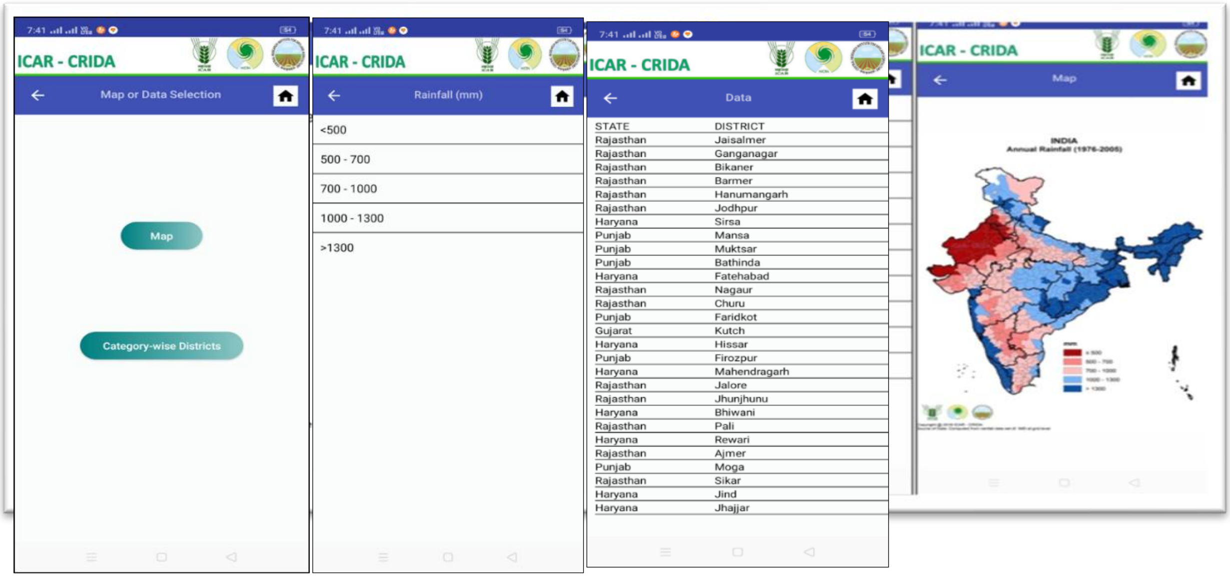

Figure 9. Information on distribution of districts based on a selected indicator

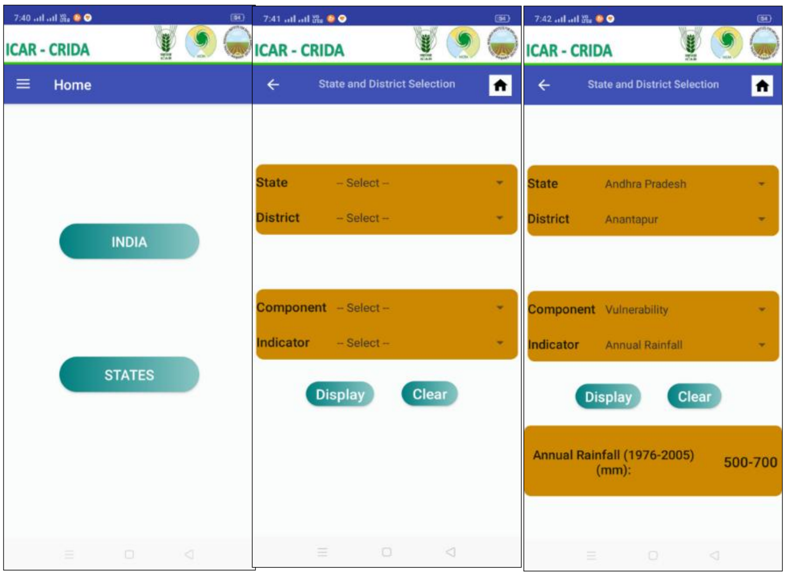

Figure 10. How to access the state-wise information

6.CONCLUSION
Any effort to boost and stabilize agricultural productivity will need to include a decision-making system based on data, as farming is now a highly time-sensitive and information-intensive endeavor, especially in the context of a changing climate. This highlights the importance of the swift and accurate distribution of vital knowledge regarding key agricultural technologies among farming communities. Therefore, it is important for farmers and other stakeholders to obtain relevant data when needed.

A major opportunity for farmers, extension workers, and other stakeholders to collaborate more effectively has arisen because of the widespread availability of mobile telephone networks. The developed mobile app "Risk and Vulnerability Assessment of Indian Agriculture to Climate Change" can enable users to access information on climate change along with its various components and indicators for a particular district. Using this information, district-specific adaptation initiatives and investments can then be designed by policymakers and extension organizations.

7.Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

8..**Author Contributions**

Conceptualization, R.N.K. and C.A.R.R.; methodology, C.A.R.R., R.N.K., and B.M.K.R.; software, R.N.K., C.A.R.R., B.M.K.R., and A.V.M.S.R.; formal analysis, R.N.K. and C.A.R.R.R.; investigation, R.N.K. and B.M.K.R.; data curation, M.S.R., G.N., and N.S. R.; writing—original draft preparation, R. N. K. and C.A.R.R.; writing—review and editing, R.N.K., C.A.R.R.R., B.M.K.R., and A.V.M.S.R. and M.S.R; supervision, C.A.R.R; All authors have read and agreed to the published version of the manuscript.

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11.**Data Availability Statement**

The data are available upon request from the authors for reasonable reasons.

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