EFFECTIVENESS OF IMAGE-BASED PLANT DISEASE DETECTION SYSTEM

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DEPARTMENT OF AGRICULTURAL EXTENSION & INFORMATION SYSTEM
SHER-E- BANGLA AGRICULTURAL UNIVERSITY, DHAKA

JUNE, 2021

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By

MD. ABDUL MALEK

Reg. No. 18-09081

A Dissertation

Submitted to the faculty of Agriculture,

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In partial fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

IN

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SEMESTER: JANUARY- JUNE, 2021

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This is to certify that the dissertation entitled **"EFFECTIVENESS OF IMAGE-BASED PLANT DISEASE DETECTION SYSTEM"** submitted to the **Faculty of Agriculture**, Sher-e-Bangla Agricultural University, Dhaka in partial fulfilment of the requirements for the degree of DOCTOR OF PHILOSOPHY in Agricultural Extension & Information System, embodies the result of a piece of bona fide research work carried out by **Md. Abdul Malek, Registration No.18-09081** under my supervision and guidance. No part of the dissertation has been submitted for any other degree or diploma.

I further certify that any help or source of information, as has been availed of during the course of this investigation has been duly acknowledged by the Author.

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DECLARATION

It is hereby declared that except otherwise stated, this Dissertation is entirely the own work of the present researcher under the guidance and supervision of the Advisory Committee and has not been submitted in any form to any other University for any degree.

The Researcher

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BIOGRAPHICAL SKETCH

The author was born on 20 January 1984 at Village- Bhelaguri, P.O- Bhelaguri, Upazila- Hatibandha, District- Lalmonirhat, Bangladesh. He came from a reputed and enlightened Muslim family. He passed his School life in the village. Then he got admitted into Rangpur Govt. College, Rangpur and passed Higher Secondary Certificate (H.S.C) examination in 2001. He obtained the degree of Bachelor of Science in Agriculture (Hons.) in 2006 and the degree of Master of Science in Agronomy in 2008 from Bangladesh Agricultural University, Mymensingh, Bangladesh.

He started his career in 2010 by joining 28th BCS as an Agricultural Extension Officer of the Department of Agricultural Extension. He has been promoted as Upazila Agriculture Officer in 2016. He is the innovator of the popular Image-based Plant Disease Detection System (IPDDS) Krishoker Janala. He is a Life Member of Bangladesh Agricultural Extension Network (BAEN), General Member of Krishibid Institution of Bangladesh (KIB), General Member of BCS (Agriculture) Cadre Association and 28th BCS Forum.

The author is married to Mrs. Fauzia Sultana (Ety) and blessed with two daughters: Tajkia Noor Naba and Afia Zarin Suba

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The Researcher

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ACRONYMS AND SYMBOLS USED

A2I	Access to Information
AEIS	Agricultural Extension & Information System
AEO	Agricultural Extension Officer
AI	Artificial Intelligence
AICC	Agriculture Information and Communication Center
AIPDDS	Automated Image-based Plant Disease Detection System
ASEI	Average Standardized Effectiveness Index
BBS	Bangladesh Bureau of Statistics
BARI	Bangladesh Agricultural Research Institute
BI	Benefit Index
BRRI	Bangladesh Rice Research Institute
DAE	Department of Agricultural Extension
DAM	Department of Agricultural Marketing
DL	Deep Learning
EI	Effectiveness Index
FAO	Food and Agriculture Organization
FFS	Farmer Field School
FY	Fiscal Year
FYP	Five Year Plan
GAP	Good Agricultural Practice
GDP	Gross Domestic Product
GO	Government Organization
GED	General Economics Division
GPS	General Packet Radio Service
GMD	Green Mite Damage
IBM	International Business Machines Corporation
ICT	Information and Communication Technology
ICT4D	ICT for Development
IPDDS	Image-based Plant Disease Detection System
IS	Information System
IT	Information Technology
ITU	International Telecommunication Union
IPDDS	Image-based Plant Disease Detection System
LDC	Least Developed Country
MIS	Management Information System
ML	Machine Learning
MoA	Ministry of Agriculture
NGO	Non-Government Organization
PEAT	Progressive Environmental and Agricultural Technologies
OECD	Organization of Economic Cooperation and Development
OI	Obstacle Index
PFI	Problem Faced Index
RMD	Red Mite Damage

RWD	Responsive Web Design
SAAO	Sub Assistant Agriculture Officers
SAU	Sher-e-Bangla Agricultural University
SBI	Standardized Benefit Index
SPSS	Statistical Package for the Social Sciences
SBI	Standardized Benefit Index
SEI	Standardized Effectiveness Index
SOI	Standardized Obstacle Index
SUI	Standardized Use Index
SVM	Support Vector Machine
TAM	Technology Acceptance Model
TPB	Theory of Planned Behavior
UAO	Upazila Agriculture Officer
UNCTAD	United Nations Conference on Trade and Development
UI	Use Index
USA	United States of America
UTAUT	Unified Theory of Acceptance and Use of Technology
WB	World Bank
approx.	Approximate
BDT	Bangladeshi Taka
B	Beta
CV	Co-efficient of variance
Df	Degree of freedom
DoI	Diffusion of Innovation
doi	Digital Object Identifier
eg.	exempli gratia (for example)
et al.	et all (and other people)
etc.	et cetera (and the rest)
G	Gram
H_0	Hypothesis
i.e.	id est (that is)
Kg	Kilogram
SD	Standard Deviation
RH	Relative Humudity
sq.km	Square Kilometer
sq. mile	Square Mile
Tk./tk.	Taka
USD	United States Dollar
TV	Television
viz.	videlicet (namely)

Effectiveness of Image-based Plant Disease Detection System

Md. Abdul Malek

ABSTRACT

Image-based Plant Disease Detection Systems (IPDDSs) are increasingly used in agriculture for detecting plant diseases. A good number of models and techniques are used for this purpose. Usually, the effectiveness of these models and techniques is studied from developers' perspectives. This study intended to find out the effectiveness of IPDDS in detecting plant diseases from the users' perspectives. A total of 384 IPDDS users across Bangladesh were selected randomly and interviewed during the period from May 01, 2021 to September 30, 2021. Major findings indicated that the majority of the users (77.90%) perceived IPDDS as moderately effective while 19.50% of the users perceived IPDDS as highly effective, and 2.60% perceived it as less effective in detecting plant diseases and getting plant disease-related services. Among the effectiveness dimensions 'user satisfaction' ranked first followed by 'system accuracy', 'user friendliness', 'content quality', 'offline usability', and 'device responsiveness' based on the Average Standardized Effectiveness Index (ASEI). According to the descending order of the Standardized Effectiveness Index (SEI), 'on-time service' ranked first followed by 'time needed for getting service', 'service cost', 'delivery of the service', 'ease of the system', etc. Step-wise multiple regression showed that out of 14 selected characteristics of the IPDDS users, four (4) characteristics namely, 'time saved', 'knowledge on plant disease management', 'benefits obtained by using IPDDS', and 'use of ICT' had significant positive contribution and 'obstacles faced in using IPDDS' had significant negative contribution to their perceived effectiveness of IPDDS. These five (5) variables explained 34.5 percent of the total variation in the effectiveness of IPDDS. Each of the Five (5) variables had indirect effect on the effectiveness of IPDDS through the other four (4) variables. According to the descending order of Standard Benefit Index (SBI), 'reduce time for detecting plant disease' ranked first followed by 'increase service accessibility', 'increase service quality', 'increase respondents' knowledge', etc. According to the descending order of Standardized Obstacle Index (SOI) 'illiteracy', ranked first followed by 'inability of disease detection at an early stage', 'unavailability of the smart phone', 'ICT phobia', 'inadequate extension service to support the use of IPDDS', etc. Frequently suggested suggestions by the users included covering all stages of the disease, providing farmers' training, introducing off-line system, comparison system, voice interactive system, intelligent system, image uploading option, etc. Based on the suggestions of the users and the findings of the research, a functional model for improving DPPIS is proposed.

CHAPTER 1
INTRODUCTION

1.1 Background of the Study

1.1.1 General background

The use of Information and Communications Technology (ICT) and the understanding of its potentials to transform farming from labor-intensive farming to smart automated farming are increasing significantly among the farming community. The Smartphone powered by novel sensing technologies, Artificial Intelligence (AI), and Machine Learning (ML) algorithms solve complex daily problems efficiently creating a new intelligent intermediary layer between people and systems. That is why users want to be connected to use data and information in real-time (Mendes *et al.*, 2020). The use of mobile communications has increased exponentially in the last many years. In 2019, 225 billion mobile applications were downloaded by consumers, and by 2023 it is projected that this number grows to about 299 billion (Statista, 2021). These trends are visible in the agricultural field also. Plantix – an Image-based Plant Disease Detection System (IPDDS) has been installed more than 15 million as of 9 November 2021 (Plantix, 2021). Mobile phone applications designed for smallholder farmers to improve decision-making have been revolutionizing the agriculture sector (Thar *et al.*, 2021). Image-based Plant Disease Detection System (IPDDS) is a system where images are used to detect plant diseases. Several smartphone applications are available and are being used by farmers, gardeners, and agricultural advisory service providers. A farmer or user can use an image library to identify plant disease or upload images to identify plant disease using these applications. Several techniques are used in IPDDS such as using machine learning (R. U. Khan *et al.*, 2021; Kothari, 2018; Ramesh *et al.*, 2018; and Yang and Guo, 2017) using support vector machines (D. Das *et al.*, 2020; Islam *et al.*, 2017; Kaur and Kang, 2015; and Zhou *et al.*, 2013), image processing (Camargo and Smith, 2009; Khirade and Patil, 2015;

Vetal and Khule, 2017; and Vishnoi *et al.*, 2020). Besides- Artificial Neural networks (Pawar *et al.*, 2016) and Convolutional Neural Networks (Boulent *et al.*, 2019) are also used for IPDDS. A good number of IPDDS have been used by farmers for detecting plant disease. Most used IPDDS are presented in Table 1.1 with developer, source, key features, and download as of 26 December 2021.

Table 1.1 Most used IPDDS in agriculture with developer, source, key features, and Download as of 26 December 2021.

Name of IPDDS	Developer and Source	Key features	Download
Plantix	Progressive Environmental and Agricultural Technologies (PEAT) GmbH (Berlin, Germany), (Plantix, 2021)	1. Uses image recognition and deep learning (DL) algorithms 2. Detect diseases, pests, and nutritional deficiencies in plant 3. Covers 500 diseases of 30 crops and available in 18 languages.	15,00,00,000
Krishoker Jananala	DAE, Access to Information (A2I) and Codex software solution ltd, Bangladesh, (Codex, 2020; Malek, 2015a)	1. Image-based system of plant disease detection. 2. Provides solutions to more than 1000 problems of 120 crops. 3. Off-line and online usability	1,50,000
Plant Disease	The Technological Educational Institute of Thessaly (Larissa, Greece), (Petrellis, 2019). (Kirill Sidorov, 2021)	1. Developed using the fuzzy-like classification method. 2. Can detect disease with accuracy between 80% and 98%. 3. Off-line and online usability	1,00,000
ImScope	Walter J., (Walter J., 2021)	1. False color, image processing instrument 2. Evaluate plant health indicators. 3. Off-line and online usability.	50,000
Agrobase	Farmis (Kaunas, Lithuania), (Farmis, 2021)	1. Identify diseases, insects, or pests and get solutions for crop protection. 2. Includes vegetable, fruit, nut, horticultural crops.	50,000

Table 1.1 Most used IPDDS in agriculture (Contd.)

Name of IPDDS	Developer and Source	Key features	Download
BioLeaf	Federal University of Mato Grosso do Sul (Campo Grande, Brazil), (Machado *et al.*, 2016) , (Upvision, 2021)	1. Can measure the infested area of a plant leaf beside identification of diseases 2. Useful on the plant resistance evaluation.	10,000
ADAMA Bullseye	ADAMA Agricultural Solutions, (Adama, 2021)	1. Image-based system of plant disease detection. 2. Covers pests and diseases in rice, almonds, tomatoes, apples, watermelon and cotton crops. 3. Off-line and online usability	1,000
Plant Doctor	Aerotech Design Studio, Grace Park West, Caloocan, Metro Manila, Philippines, (Aerotech, 2021)	1. Uses machine learning models to detect the conditions of plants 2. Covers apple, strawberry and tomato.	1,000
CropsAI	Spacenus (*Spacenus*, 2021)	1. Automatically detects diseases 2. Makes recommendations	1,000

Snapshots of mobile applications of some IPDDS may be seen in Appendix II.

1.1.2 Global perspective

Plant diseases cost the global economy around $220 billion annually (FAO, 2021). There is no alternative to develop modern technology and ensure effective agricultural advisory services to the growers to cope with the situation. The basic agronomic principles can ensure the maximum yield from a crop variety, such as proper land preparation, selection of quality seeds and suitable varieties, proper water management, nutrient management, accurate pest management, proper harvesting, and postharvest operations (Hasanuzzaman, 2019). Agriculture has graduated from agriculture 1.0 to agriculture 4.0 resembling industry 4.0 and smart farming is the reality of agriculture 4.0. These gradual developments in the field of agriculture and the reality of agriculture 4.0 and onward or smart agriculture indicate the gravity of the intervention of ICT in the agricultural sector. One of the major concerns of industry 4.0 and hereby agriculture 4.0 is that the use of the automated system will be increased and human labor involvements will be reduced. In these circumstances, the need for machine learning or artificial neural network, or artificial intelligence-based IPDDS will just widen the space for agriculture 4.0 and onward.

FAO has considered ‘Agricultural productivity and innovation’ and ‘Transboundary pests and diseases’ as two major drivers of change in agriculture in the 21st century. The potentiality of mobile phones can be used in disseminating agricultural innovation for combating pests and diseases. Mobile phones with IPDDS and other state-of-the-art technologies shorten the distance between isolated smallholder farmers and other actors involved in production, processing, transporting, marketing, and regulating food. Face-to-face extension services are being complimented, and sometimes replaced, by mobile phones, the Internet, and more conventional media, such as radio, video, and television. In many countries, extension services have evolved away from top-down ‘technology transfer’ to participatory and discovery-based approaches that inspire innovation (FAO, 2017). Tomorrow’s agriculture is going to boost up combating the local problems with global solutions through the intervention of ICTs.

1.1.3 Bangladesh perspective

Bangladesh is going to be graduated from Least Developed Country (LDC) to developing country through the acceptance of the proposal in the United Nations (UN) general assembly in 2021. Still, the country has to fight against several challenges. Boosting agricultural production can be a way for fighting the challenges. But the farmers of the country face several problems in growing crops like inadequate supplies of fertilizer, pesticides in local markets (Quddus and Kropp, 2020), loss of arable land, population growth, climate changes, inadequate management practices, unfair price of produces, and insufficient investment in research (Mondal, 2010). Constrains of inadequate supply of pesticides are associated with infestation of pests and diseases etc. Although Bangladesh has got very grass root level agricultural extension services, the farmers often suffer from a lack of information and advice during the infestation. To get necessary information and advice from Upazila Agriculture Office (UAO), farmers visited almost 5 to 30 Kilometers. Sometimes visiting the long distance to UAO, farmers failed to meet with Upazila Agriculture Officer or other service providers. When farmers came to the UAO or an agricultural extension service provider, sometimes they failed to come with a symptom of the disease or failed to explain the problem to the extension service provider clearly and thus it became difficult for the extension service provider to identify the disease. The service provider then had to make a field visit to identify the problem and suggest the requisite solution to overcome the problem (Malek, 2015a). Considering the problems faced by Bangladeshi farmers in getting agricultural advisory services. Malek (2015a) designed an image-based plant's problem (pest and disease) identification system later get popular as Krishoker Janala. In this connection, it is important to know how much distance has been shortened, how much time to get services have been reduced, and how to feel the recipients of the service after getting a new intervention.

Strengthening Management Information System (MIS) and ICT-based knowledge management systems and e-agriculture has been taken as a strategy for developing the agriculture sector of Bangladesh in the Bangladesh Eighth Five Year Plan (July 2020-June 2025) (GED, 2020). Bangladesh has also taken an action plan for increasing women and youth participation in agriculture (GED, 2020). To ensure this, the use of ICT-based knowledge management systems like IPDDS is a must.

Considering the general background, global and Bangladesh perspectives, it can be said that the use of knowledge-based technology like IPDDS is irresistible. Now the question is how it can be made more feasible in terms of effectiveness. This study believes that the findings of the study will show a path for the policymakers, IT industry, and agriculture extension personnel to solve the question.

1.2 Statement of the Problem

A good number of models for IPDDS have been developed and their accuracy value is very high for example -Tetila *et al.* (2020), Wallelign *et al.* (2018), Sandino *et al.* (2018), Sibiya and Sumbwanyambe (2019) and Prakash *et al.* (2017) developed models for IPDDS and they claimed accuracy value of their models as 99.04%, 99.35%, 97.35%, 92.85%, and 90% respectively. Some of the models have been implemented and tested in real field situations by entrepreneurs or start-ups. But the effectiveness of very few of them has been studied from the user perspective. Entrepreneurs or start-up companies are bringing innovations and technologies to the users in the agricultural field. Despite the importance of the entrepreneurs' role in the process of innovation adoption, the issue needs to be analyzed from the end-user's viewpoint. The effectiveness of IPDDS depends upon many factors. The system characteristics and users' characteristics are two important sets of characters. There is an anonymous saying in the IT industry that, the more unsmarted the user, the more the system needs to be smart or intelligent. However, the present study would attempt to find out the answer to the following research questions:

i. What were the purpose of using IPDDS and what were the Profession, Gender, and Geographical regions of the IPDDS users?
ii. What was the extent of the effectiveness of IPDDS as perceived by the users?
iii. What were the characteristics of the IPDDS users?
iv. What were the contributions and effects of the selected characteristics of the user to/on their perceived effectiveness of the IPDDS?
v. What were the comparative benefits of using IPDDS and what obstacles faced by the users in using IPDDS?
vi. What would be the functional model for improving IPDDS as per suggestions of the users?

1.3 Objectives of the Study

To shape the research in a manageable and meaningful way, the following specific objectives were formulated:

- ❖ To determine the purpose of using IPDDS and to describe the Profession, Gender, and Geographical regions of the IPDDS users
- ❖ To determine the effectiveness of IPDDS as perceived by the users
- ❖ To determine the characteristics of the IPDDS users
- ❖ To explore the contribution and effects of the selected characteristics of the users to/on their perceived effectiveness of the IPDDS
- ❖ To compare the benefits obtained by using IPDDS and obstacles faced in using IPDDS
- ❖ To develop a functional model for improving IPDDS as per suggestions of the users

1.4 Justification of the Study

Policymakers are very keen to know the impacts of ICTs. They are interested in both economic and social impacts (Roberts and Spiezia, 2009). The use of IPDDS is increasing day by day. It is an opportunity to reach the farming community with advanced agricultural advisory services. Therefore, it is immensely needed to find out the effectiveness of IPDDS to draw attention so that government can enhance the system. The involvement of various stakeholders is a very crucial point to be considered in this connection. For ensuring the involvement of the IT industry and other stakeholders, the role of each stakeholder needs to be found out. The findings of the study are desired to help the policymaker in understanding the need for using IPDDS, obstacles in using IPDDS and also suggestions for improving IPDDS. The justification of the study can be summarized as follows:

1. The use of IPDDS is continuously increasing therefore the effectiveness of IPDDS needs to be known so that decisions can be taken on its enhancement or closing.
2. For improving IPDDS, obstacles of using IPDDS needs to be known.

1.5 Scope of the Study

In this study, the effectiveness, benefits, obstacles of using IPDDS were found out. What new windows are waiting to be opened by IPDDS were also determined. The study explored the characteristics of the users and also found out the contribution of selected characters of users to the effectiveness of IPDDS. This study collected suggestions of users for improving IPDDS and also proposed a functional model for developing IPDDS. The findings are desired to play important role in a policy decision, developing strategical planning, and also in implementing a good IPDDS. In brief, the scopes of the study are:

- Policymakers and planners can use the findings to formulate knowledge-based e-agriculture policy; and
- IT industry will get indication regarding trends of use of ICT and demands of IPDDS in agriculture that help to improve the usability of IPDDS.

1.6 Assumptions

The researcher had the following assumptions in mind while undertaking this study.

1. The respondents selected for the study were competent enough to answer the queries made by the researcher.
2. The respondents included in the sample were capable of furnishing proper responses to the questions included in the interview schedule.
3. The views and opinions provided by the farmers included in the sample were the representative views and opinions of all users.
4. The data collected by the researcher from the respondents were free from biases.
5. The items, questions and variables were reasonably adequate to reflect the respondents' real views and opinions.
6. The scales used for the study were valid and reliable.
7. The findings of the study were expected to be useful for planning and implementation of various extension programs for improving advisory services.

1.7 Limitations

The study had the following limitations:

1. The respondents of the study were from the whole country; therefore, heterogeneity was found in the case of some variables.
2. Characters of the users were many and varied, but in the present study only fourteen (14) factors on personal, socio-economic, and professional characteristics were taken into consideration. Factors related to the system were not included as variables of the study.
3. There were many kinds of IPDDS but only three (3) kinds were found in Bangladesh.

1.8 Definition of Terms

Terms used throughout the study are defined and interpreted below for clarity of understanding. The measuring techniques are discussed in chapter 3 of this dissertation:

Agricultural advisory services

Agricultural advisory service referred to the agricultural advice provided to the farmers or agro-entrepreneur to manage problems related to crop pests and diseases. General advice is also included in agricultural advisory services.

Image-based Plant Disease Detection System (IPDDS)

IPDDS or an Image-based Plant Disease Detection System is a system where the image is used to detect plant disease using deep learning (Mohanty *et al.* 2016). Besides deep learning other techniques like machine learning, neural network etc. are also used in this case. Several smartphone applications are available and are being used by farmers, gardeners and agricultural advisory service providers for detecting plant diseases and getting or providing advisory services.

Age

Age referred to the period of respondent users of IPDDS from their birth to the time of interview.

Education

The education of an individual was defined as the extent of formal education received by him from the educational institute or adult learning center.

Crop farm size

It refers to the effective cropped area by the respondent’s own or taken as a lease from others.

Annual crop production income

Annual crop production income referred to the total earnings of respondents and the members of their family from crop agricultural sources (cereals, fruits, vegetables etc.) during the previous year.

Individual extension contact

Individual extension contact of a respondent was measured by the extent of contact with 5 selected agricultural extension media such as neighbor/relative farmers**,** model/leader farmers, agricultural input dealers (seed, fertilizer, pesticides etc.), block/union level extension agents (GO/NGO)**,** Upazilla or above level extension service providers.

Knowledge on plant disease management

Knowledge, as defined in this study, included 'those behavior and test situations which emphasized the remembering either by recognition or recall of ideas, material or phenomenon'(Bloom, 1956). This variable indicated the extent of knowledge on plant disease management of the respondents at the time of the interview as evident from their responses to a set of questions logically and scientifically prepared for this purpose.

Extent of use of IPDDS

It refers to the frequency and type of IPDDS used by users for detecting diseases of their crops.

Obstacle faced in using IPDDS

It refers to the extent of obstacles faced by the users during using IPDDS for detecting diseases of their crops.

Benefits gained by using IPDDS

It refers to the extent of opportunity obtained by the users during using IPDDS for detecting diseases of their crops.

Use of ICT

Information and Communication Technology (ICT) is defined as the hub of technologies that support storage, processing data/information, communication of data/information, and distribution of data. ICT therefore, comprises technologies such as computers (desktop and laptop), mobile phones, Internet connection, peripherals, and software that are projected to perform information processing and communication purposes (Ali *et al.*, 2019). Use of ICT refers to the frequency of ICTs used by a user. The extent of ICT use for agricultural purposes refers to the extent of ICTs used by respondents for farm-related activities while non-farm related purposes are referred to as general purposes.

Farming experience

The farming experience of the respondents was measured by the number of years a respondent engaged in crop cultivation. The measurement included the year of starting of first crop cultivation until the year of data collection.

Time saved

Time saved refers to the amount of time saved by the respondents by using IPDDS in getting plant disease-related services. It was measured in hours.

Cost saved

The cost saved refers to the amount of cost saved by the respondents by using IPDDS in getting plant disease-related services. It was measured in Bangladeshi Taka (BDT).

Visit saved

Visit saved refers to the frequency of visits saved by the respondents by using IPDDS in getting plant disease-related service. It was measured in frequency.

Effectiveness of IPDDS

Effectiveness is the state of producing the intended or expected result of a program or project within the desired period. Effectiveness of IPDDS refers to the expected achievements gained by a user by using IPDDS. In the IT industry effectiveness of a system is measured by measuring some matrices like audience gain, retention rate, user activity, average session length, and monetization index (NinjaPromo, 2019). The present study found that those matrices are from the developer side not covering user perspectives.

In the present study, the effectiveness of IPDDS was measured by a scale developed for this study by the aggregation of system accuracy, off-line usability, user-friendliness, content quality, device responsiveness and user satisfaction. The details were stated in chapter 3.

Matrices used in the IT industry and users' perspectives have been taken into consideration in developing the scale for measuring the effectiveness of IPDDS.

System accuracy

Accuracy can be defined as the degree to which the result of a measurement, calculation, or specification conforms to the correct value or a standard. Accuracy is important in software engineering. Accuracy is the mapping of the business needs to the programmer's model. However, accuracy is much hard to obtain because it is the closeness actually what the customer needs (Moore, 2004). The current study measured accuracy as the degree of the properness of identification of plant disease, smoothness of working system, and minimization of error in the system.

User-friendliness

User-friendliness is the degree to which an innovation is perceived as relatively easy to understand and use (Rogers, 2003). User-friendly means that for customer app is intuitive, easy to use, simple, and that the customer can rely on the product (ItCraft, 2019)**.** It refers to the degree to which a system is easy to learn, use, understand, or deal with. The current study considered user-friendliness of IPDDS with 'easy to use', 'easy to remember how to use', 'lower size of the software', 'lower device hanging tendency', and 'comfort to use'.

Off-line usability

Off-line usability refers to the opportunities for software to be used in offline mode. The current study measured the offline usability of IPDDS with the scope of off-line running, off-line installation, and off-line sharing.

Device responsiveness

Responsive web design, also called Responsive Web Design (RWD) design, describes a modern web design approach that allows websites and pages to render (or display) on all devices and screen sizes by automatically adapting to the screen, whether it's a desktop, laptop, tablet, or smartphone. It was measured with 'running in any smart device', 'requirement of lower processor' and 'platform operability'

Content quality

Content quality refers to the quality of advice provided through IPDDS. It was measured by the usefulness of the content, updates of content and validity of the content.

User satisfaction

Kotler (2000) defined satisfaction as the feeling of pleasure or disappointment one experiences after comparing the perceived performance or outcome of a certain product with one's expectations. In the context of the mobile app, user satisfaction is one of the most important factors facilitating the prevalence of mobile data applications and services (Kim, 2012). In this research user satisfaction was measured by measuring 'ease of the system', 'delivery of the service', 'service cost', 'on-time service' and 'time needed for getting service'.

1.9 Organization of the Study

The study is organized under the following five (5) Chapters (as per the format and style of thesis writing for M.S/ Ph.D. degree of Sher-e-Bangla Agricultural University):

Chapter 1 - Introduction: Describes the importance of the topic, key issues, objectives, scope and limitations of the study.

Chapter 2 - Review of Literature: A brief review and definition of concepts, economic models and results of the related studies are done.

Chapter 3 - Materials and Methods: Explains the sampling design, method of data collection and tools of statistical analysis used in the study.

Chapter 4 – Results and Discussion: Explains the findings and discussions including the purpose of using IPDDS, the Profession, Gender, and Geographical region of the IPDDS users, the effectiveness of IPDDS as perceived by the user, the characteristics of the IPDDS users, the contribution and effects of the selected characteristics of the user to their perceived effectiveness of the IPDDS, the benefits obtained by using IPDDS and obstacles faced in using IPDDS, and functional model for improving IPDDS as per suggestions of the users.

Chapter 5 - Summary, Conclusion and Recommendations: A brief summary of work done, the salient findings and inferences drawn and their implications for policy are presented.

CHAPTER 2
REVIEW OF LITERATURE

To form a bridge between the past and present research works related to the problem, an exertion was made in this Chapter. It represents a brief review of related research information which gives a very clear direction to the researcher for the selection of research issue by identifying the research gap. The researcher made an elaborate search of available literature to review the findings of past researches in this respect. However, some studies were found to be related broadly to the present study but not systematic and directly related to the present study. Therefore, an attempt has been made to review and document closely related literature. In this Chapter available from books, journals, review papers, concept notes, online resources, and literature have been reviewed and illustrated in different sections where, section 1 discussed with concept and Types of IPDDS, section 2 discussed studies related to the development and evaluation of IPDDS, section 3 discussed with literature related to challenges of developing and using IPDDS, section 4 discussed with literature related to the factors of the effectiveness of IPDDS, section 5 discussed with approaches used to measure the effectiveness of ICT innovation, section 6 discussed with challenges in measuring the impacts of ICT, section 7 discussed with theories related to measuring the effectiveness of IPDDS, section 8 discussed the conceptual model of the study.

2.1 Concept and Types of IPDDS

IPDDS is a system where the image is used to detect plant disease through computer vision technology (R. U. Khan *et al.*, 2021) or visual comparison (Adama, 2020; Malek, 2015b). IPDDS is also termed as 'Vision-Based Plant Disease Detection System' by (Cruz *et al.*, 2017). Although Cruz *et al.* (2017) used the word 'Vision-Based' to mean 'computer vision', can be used generally to mean both computer and eye vision.

Broadly, two types of IPDDS were found in literature, computer vision-based IPDDS and image library-based IPDDS.

2.1.1 Computer vision-based IPDDS

Computer vision is a field of Artificial Intelligence (AI) that enables computers and systems to derive meaningful information from digital images, videos, and other visual inputs and take actions or make recommendations based on that information (IBM, 2021). Some examples of computer vision-based IPDDS with technology/model, number image used for training model, accuracy claimed and sources are shown in Table 2.1.

Table 2.1 Computer vision-based IPDDS

Technology/ model used	No. of image used for training model	Accuracy claimed (%)	Source
Convolutional neural network	54305	99.00	Reddy *et al.* (2021)
Deep learning algorithm	7600	98.00	Guo *et al.* (2020)
Image segmentation	20	96.10	Lin *et al.* (2019)
Explainable 3D deep learning	111	95.70	Nagasubramanian *et al.* (2019)
Deep learning meta-architectures	61486	73.00	Saleem *et al.* (2020)
EfficientNet deep learning	55,448 and 61,486	99.91 and 99.97	Atila *et al.* (2021)
Color texture features and discriminant analysis,	-	95.00	Pydipati *et al.* (2006)
Hyperspectral image analysis	-	76.30	Lowe *et al.* (2017)

2.1.2 Image library-based IPDDS

There are some IPDDS where plant diseases are identified by comparing the diseases visually with an image library of the system. These types of IPDDS are reported by (Adama, 2021; Malek, 2015a). In this case, the user identifies plant disease comparing with the image library of the system. Some system has got image library based IPDDS and computer vision-based IPDDS combined as reported by (Adama, 2021).

2.2 Studies Related to Development and Evaluation of IPDDS

Most of the studies found from the literature are about developing models on IPDDS, training models with available plant disease image data set and evaluating the model with a standard data set. The majority of the researcher like Guo *et al.* (2020), Atila *et al.* (2021), Ashqar and Abu-Naser (2019), and Khan *et al.* (2020) used 'plant village' data set – a free dataset of plant disease to use in training model. Related works on IPDDS are reviewed here in two major headings lab-based study and field-based study.

2.2.1 Lab-based study and evaluation of models of IPDDS

To identify plant disease automatically, Mohanty *et al.* (2016) developed a deep convolutional neural network-based system. They used a public dataset of 54,306 images of diseased and healthy plant leaves and found an accuracy of 99.35% on a held-out test set and they claimed it as a demonstration of the feasibility of their approach. They collected the images under controlled conditions and they trained a model to identify 14 crop species and 26 diseases (or absence thereof). Similar works have been done by (Liu *et al.*, 2018), (Li *et al.*, 2018), (Arsenovic *et al.*, 2019), (Saleem *et al.*, 2020), (Mishra *et al.*, 2020), Guo *et al.* (2020), (Bansal *et al.*, 2021), Reddy *et al.* (2021), and others. Ferentinos (2018) suggested the models as very useful advisory or early warning tools, and expandable to support an integrated plant disease identification system to operate in real cultivation conditions (Ferentinos, 2018).

Islam *et al.* (2017) integrated image processing and machine learning to diagnose diseases from leaf images. Their automated method classified diseases on potato plants from publicly available plant image database 'Plant Village'. They used a segmentation approach and a Support Vector Machine (SVM) and obtained an average accuracy of 95%.

Ramcharan *et al.* (2017) used the best-trained model to study cassava disease and found accuracies of 98% for brown leaf spot (BLS), 96% for Red Mite Damage (RMD), 95% for Green Mite Damage (GMD), 98% for Cassava Brown Streak Disease (CBSD), and 96% for Cassava Mosaic Disease (CMD). They reported an overall accuracy of 93% for data not used in the training process.

All the above-mentioned initiatives are found to be very sophisticated. High-level technology has been used and a huge cost and resources are involved. Implementation of the service needs to invest high capital and resources. The studies were done mostly at the laboratory level. Only the accuracy of the developed model was tested against a standard database. In some cases, the same dataset was used in training and testing the model. Therefore, the performance of those models in the real field is yet in question.

2.2.2 Real field study of IPDDS

Some of the models discussed in the previous sub-section have been used to develop applications for detecting plant diseases and are being used by the farmer at the field level. But very few studies were found to be intended to measure the effectiveness of those applications. Rupavatharam and Kennepohl (2018) studied ‘Plantix’ the most used IPDDS that assists in detecting damage on plants with the help of a smartphone image. They reported 90% accuracy of the system for 100 classes. Tan *et al.* (2018) introduced a mobile application named AuToDiDAC or Automated Tool for Disease Detection and Assessment for Cacao Black Pod Rot (BPR) that automatically detects, separates, and assesses the infection level of BPR in cacao through image processing and machine learning techniques. They reported an average of 84% accuracy on an independent test set of ten cacao pod images. Arsenovic *et al.* (2019) conducted several experiments to test the impact of training in a controlled environment and usage in real-life situations to accurately identify plant diseases in a complex background and various conditions including the detection of multiple diseases in a single leaf. Finally, they proposed a novel two-stage architecture of a neural network for plant disease classification focused on a real environment. They claimed that the trained model achieved an accuracy of 93.67%. Malek (2015b) studied Krishoker Janala – an image library-based IPDDS and reported that 94% of the user respondents had the opinion that the new intervention (Krishoker Janala) was most suitable for them, through using the database cost of delivering service or having service (up to 86%), the time needed for delivering service or having service (up to 66.67%) while an average number of visit (48%) were reduced. Sultana *et al.* (2019) also studied the effectiveness of ‘Jrishoker Janala’ and reported that 64.2% of the user respondents perceived that the use of ‘Krisoker Janala’ is moderately effective while 24.5% and 11.3% of them perceived as less and high effective respectively.

2.3 Literature Related to the Challenges of Developing and Using IPDDS

Arsenovic (2019) conducted several experiments to test the impact of training models in a controlled environment and usage in real-life situations and observed – a small number of examples in the dataset, a small number of plant species/diseases, low accuracy when testing in real conditions, complex background, multiple diseases in the same sample, train and test data are from the same database, using images acquired in real conditions, accurate classification of the disease, disease stage identification as challenges in developing and using IPDDS. Barbedo (2016) reviewed the main challenges in automatic plant disease identification based on visible range images and reported that the presence of complex backgrounds in the image, undefined boundaries of the symptoms, uncontrolled image capture conditions, characteristics that make the image analysis more difficult, symptom variation, presence of multiple symptoms simultaneously are the major challenges of detecting plant diseases using IPDDS. R. I. Hasan *et al.* (2020) studied Deep Learning (DL) as a technique for plant diseases detection found out several challenges in plant disease detection and crop management. Their presentation is presented in Fig. 2.1.

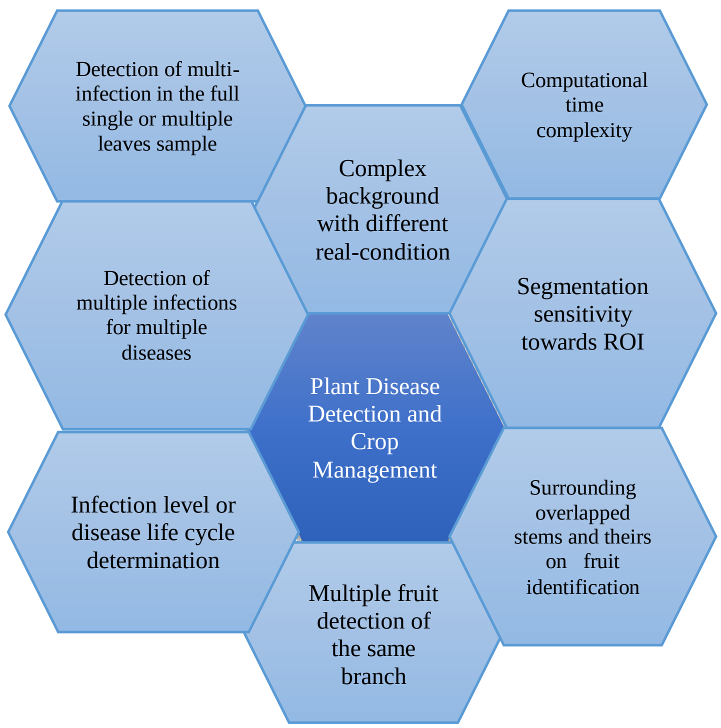

Fig. 2.1 Challenges of plant disease detection and crop management (R. I. Hasan *et al.*, 2020)

2.4 Literature Related to the Factors of the Effectiveness of IPDDS

Karim *et al.* (2020) explored the relationship between the socio-economic characteristics of women farmers and their use of mobile phone application in agricultural activities and reported that age, family size, credit received, deposit, and farm size of the women farmers had no significant relationships whereas education, annual income, organizational participation, training received and ICT self-efficacy of the women farmers had a positively significant relationship with the use of a mobile phone in agricultural activities. M. S. Khan *et al.* (2017) conducted a study to determine the effectiveness of Agricultural Information and Communication Centers (AICC) in technology transfer to farmers and reported that farmers' characteristics such as education, farm size, annual family income, organizational participation, extension contact, awareness on ICT facilities, access to ICT facilities, knowledge on ICT, and training received on ICT had a significant positive relationship with their perceived effectiveness of AICC while age and household size had a negative and insignificant relationship with the effectiveness of AICC. Tata and McNamara (2018) carried out a study to assess the impact of the Catholic Relief Services (CRS) Skills for Marketing and Rural Transformation (SMART) skills and Farm book information communication technology (ICT) on agricultural extension service delivery by front-line extension officers in two counties in Kenya and reported that extension officers using the CRS SMART skills and Farm book technology worked with significantly higher numbers of farmer groups than officers in the control group. Socioeconomic factors like gender, age, and education had an impact on the use of technology and extension service delivery. Sultana *et al.* (2019) studied the effectiveness of Krishoker Janala in disseminating agricultural information on 106 Sub Assistant Agriculture Officers (SAAOs) and reported that the extent of ICT use, use of Krishoker Janala and quality of information of Krishoker Janala had a significant contribution to the effectiveness of Krishoker Janala and age, ICT ownership, problem faced in using Krishoker Janala, job experience has no significant contribution.

The untouched area on this topic is the effectiveness of IPDDS in general from the end user's viewpoint. Although studies found on some specific context on specific IPDDS like Rupavatharam and Kennepohl (2018) has studied 'Plantix', Malek (2015b) and Sultana *et al.* (2019) have studied the effectiveness of 'Krishoker Janala'. There are several types of IPDDS and used several technologies. Mendes *et al.* (2020) mention a description of several IPDDS in their study. But they did not study the effectiveness of none of them. No general study has been conducted yet to find out the effectiveness of IPDDS. A study is needed to get an idea of how these IPDDSs are doing well at the field level in general.

2.5 Approaches Used to Measure the Effectiveness of ICT Innovation

Townsend and UNCTAD (2011) suggested seven sets of ways to measure the impacts of ICT innovation. Such as:

Analytical techniques: The usual objective of an ICT impact analysis is to examine the relationship between ICT and productivity, economic growth or employment. For this purpose, econometric modelling using regression, growth accounting and input-output analysis are done. The analysis usually includes other determinants such as labour, non-ICT capital and, for firm-level studies, factors such as firm characteristics, skills and innovation (Townsend and UNCTAD, 2011).

Case studies: Although case study research method is often considered to be invalid, invaluable and improper (Yin, 2003), it is an established research method in social sciences (Teegavarapu *et al.*, 2008)**.** Much of the work on measuring ICT impacts is based on case studies, often small scale and project-based. They may be longitudinal, examining changes over time. They are generally very detailed and can involve several qualitative and/or quantitative data sources. They can take advantage of several existing, as well as new, data sources. Case studies can be used to explore causation within their scope. At the same time, case study findings are bound by the context in which they are conducted. While their results will not usually be generalizable beyond their context, they may indicate hypotheses or topics that could be assessed more broadly.

Statistical surveys: Data needed to measure ICT impacts can come from various statistical surveys, including the

- Household surveys that collect information from individuals, including their characteristics, income, expenditure, how they spend their time, how they use ICT and their perceptions of particular ICTs;
- Surveys of businesses, including those in the ICT sector, that collect information such as employment, economic performance, innovation, expenditure on ICT, use of ICT and perceptions of ICT impacts;
- Surveys of other entities such as government organizations that gather information such as employment details, economic performance, expenditure on ICT, use of ICT and electronic services offered (Townsend and UNCTAD, 2011).

Panel studies: Panel studies are longitudinal and may be survey-based, in contrast with cross-sectional surveys, which collect data at a point in time across a population. A panel is selected at the start of the study and data are collected about its members, for example, individuals or businesses, during successive periods. Such studies can be useful in examining impacts, as they can provide good baseline data and account for time lags (Townsend and UNCTAD, 2011).

Controlled experiments: Controlled experiments can establish causality by controlling all the independent variables. Therefore, the experimenter can alter a condition and observe the effect. In general, the types of studies of interest for ICT impact analysis cannot be controlled to the degree necessary to determine a cause-and-effect relationship. However, where the conditions are limited, a controlled experiment may be possible.

Administrative data analysis: An important data source in the field of ICT statistics are administrative data collected primarily for non-statistical purposes but used to form statistical indicators. The main examples are telecommunication or ICT infrastructure data collected by International Telecommunication Union (ITU) from member Governments, merchandise trade data compiled by the United Nations Statistics Division and ICT-in-education data compiled by UNESCO's Institute for Statistics. All three sources are used for the Partnership's core ICT indicators (ICT infrastructure and access, trade-in ICT goods and ICT in education indicators respectively). Even though these administrative data are not usually collected for statistical purposes, through the efforts of organizations such as ITU, the United Nations Statistics Division and the Institute for Statistics, classifications and definitions can be applied to administrative data collection to enable statistical output (Townsend and UNCTAD, 2011).

Other methodologies and data sources: Heeks and Alemayehu (2009) suggested the use of focus groups, direct observation and document examination. Scenarios may be used to establish impacts in different situations, using different sets of assumptions. Forecasting may be used to estimate the future impacts of ICT and can involve a number of techniques, data sources and assumptions. Zhang *et al.* (2016) researched 121 CIO's (Chief Information Officers). By analyzing every of the 121 CIO's perspectives in the collaborative work sessions, they generated a total of 42 ways to assess IT effectiveness. The top 12 most frequently used methods for measuring IT effectiveness are shown in Figure 2.4. Of these, customer satisfaction tops the list, followed by project metrics, operational performance etc.

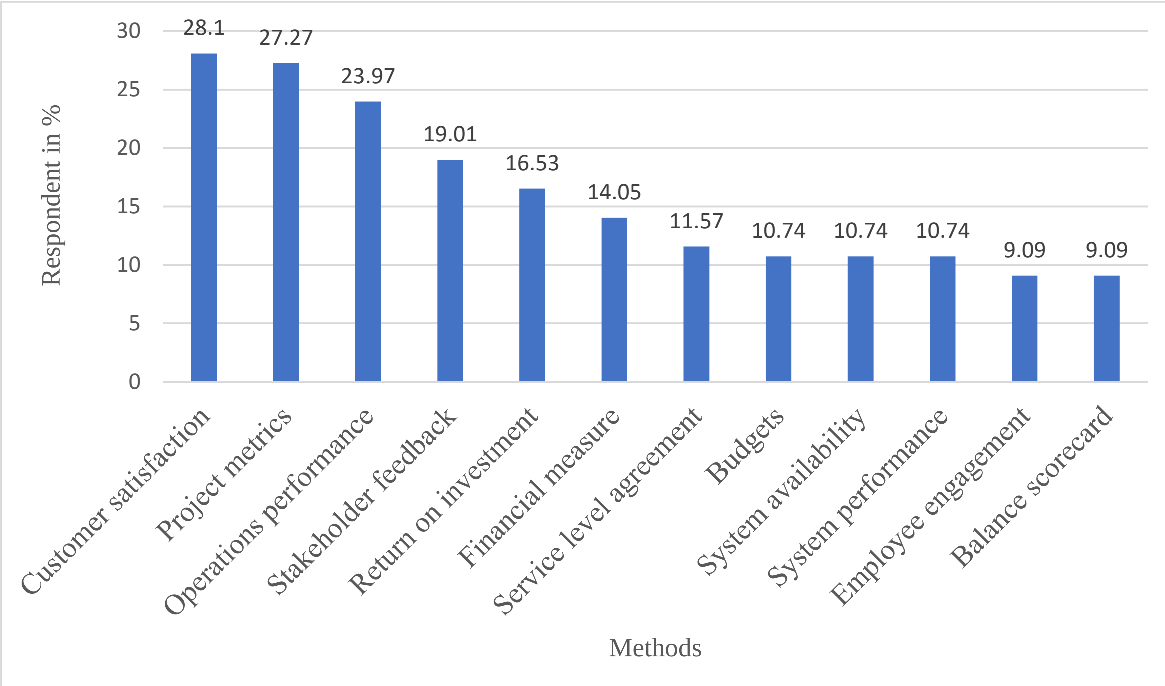

Fig. 2.2 Top 12 Methods for Measuring IT Effectiveness (Zhang *et al.*, 2016)

It is useful to consider where effectiveness lies in a broader information society. Organization of Economic Cooperation and Development (OECD) proposed a model for measuring the impact of ICT intervention. OECD (2008) model illustrate the information society and identifies the inter-related segments among ICT demand (use and users), ICT supply (the ICT sector), ICT infrastructure, ICT products, information and electronic content and ICT in a wider social and political context.

It discussed the impacts components of the conceptual model as follows:

- Impacts of ICT access and use on individuals, organizations, the economy, society and environment;
- Impacts of ICT production and trade on ICT producers, the economy, society and environment; - Impacts of use and production of content (in particular, electronic or digital content, which only exists because of ICT) on the economy, society and environment;

- Influence of other factors on ICT impacts, for example, skills, innovation, government policy and regulation, and the existing level of ICT infrastructure.

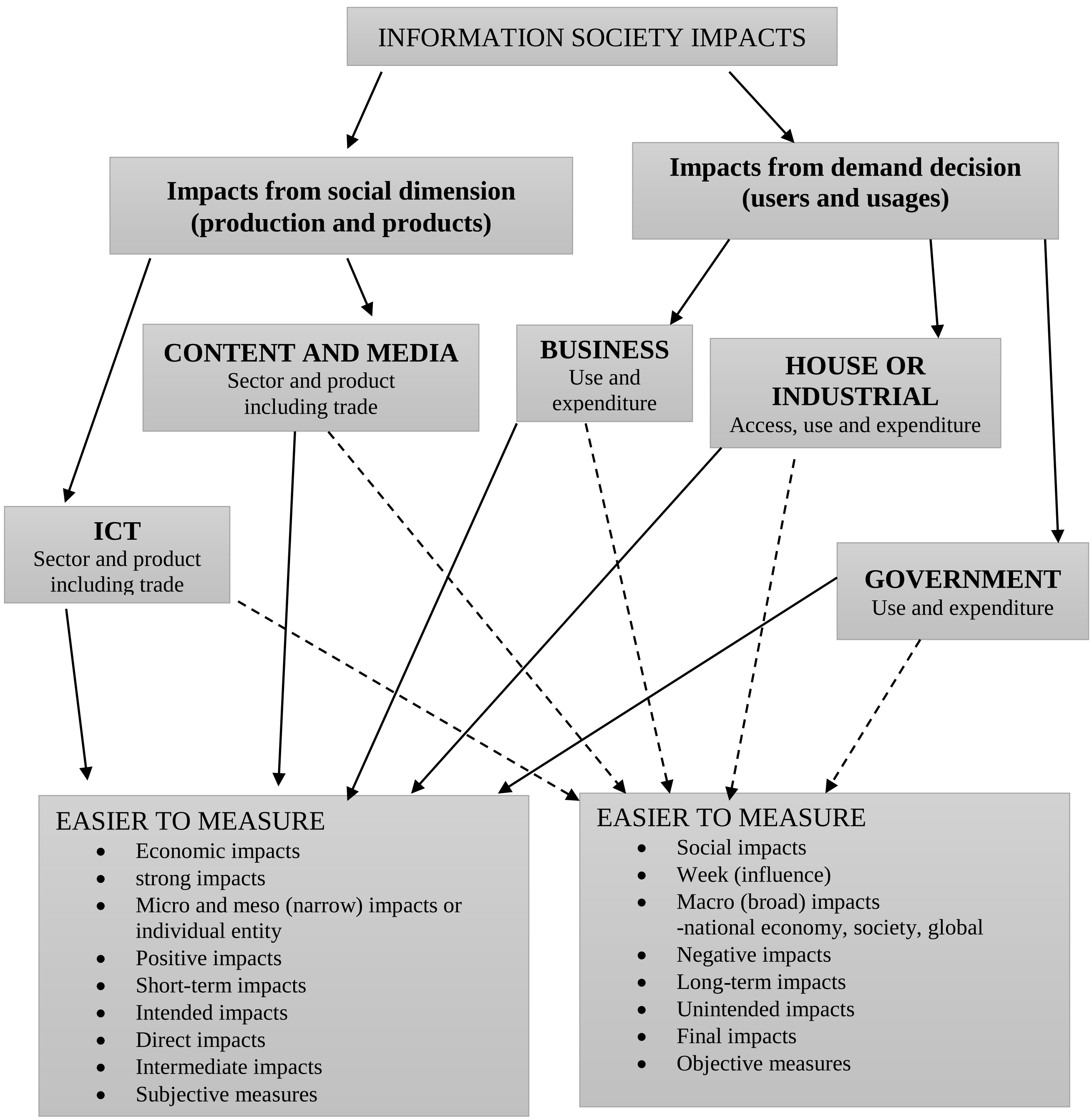

Fig. 2.3 Information society impacts measurement model (OECD, 2008)

About projects relating to information and communication technologies for development (ICT4D), an ICT4D value chain has been proposed as a basis for impact assessments (Heeks and Alemayehu, 2009). It starts with precursors and proceeds to inputs, deliverables, outputs, outcomes and development impacts. The authors consider the last three to impact and distinguish them as follows:

- Outputs are the micro-level behavioral changes associated with the ICT4D project;
- Outcomes are the specific costs and benefits associated with the project;
- Development impacts are the contribution of the project to broader development goals.

Assessment frameworks relating to ICT4D project impacts often include (Heeks and Alemayehu 2009) cost-benefit analysis, assessment against project goals, assessment of the effectiveness of communications (on changing behavior or attitudes), assessment of the impact of ICT on livelihoods, assessment of whether ICT is meeting information requirements, cultural-institutional impacts and impacts on enterprise performance, relations and value chain (Townsend and UNCTAD, 2011)

Heeks and Alemayehu (2009) gave another approach (Figure 2.4) to set the focus over time to study the impact of ICT4D projects.

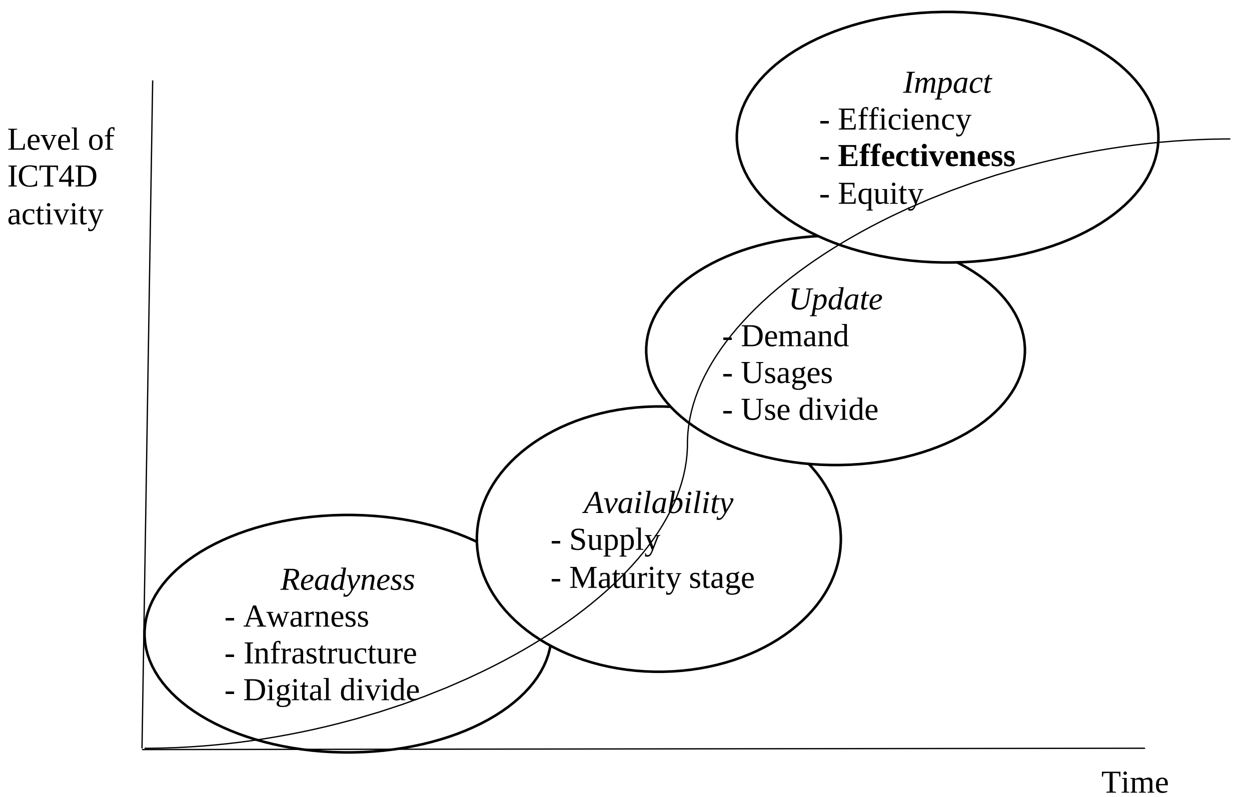

Fig. 2.4: Changing Focus of ICT4D Assessment Over Time (Heeks and Alemayehu, 2009)

There are strengths and weaknesses of the different approaches and data sources. In the case of analytical techniques, existing data are used here. Therefore, they are inexpensive, compared with other approaches. However, they will be limited to the extent that models are imprecise or input data are inconsistent, inaccurate or lacking in availability. Well-conducted statistical surveys can provide representative data about the population being measured. Their output can be cross-classified by several characteristics such as the age of individuals, or industry of a business. While surveys are generally expensive to conduct, their results are essential inputs to many of the analyses discussed in this section. Survey results are subject to several sources of sampling and non-sampling errors, and a high degree of harmonization of statistical standards is required to enable international comparison of survey output. National statistical surveys of households and businesses are the basis for the Partnership's core indicators on ICT use. Panel studies can be very useful in the following change over time in individual units, for example, people or businesses. One of their advantages is that such data enable investigation of causality where the phenomena being investigated are subject to time lags. However, panel studies can be expensive, especially if the panel is large, and suffer from attrition, that is, loss of units over time. Controlled experiments are problematic for this topic, as the number of factors involved in an ICT impact can be very large, and some unknown. In case studies, results are likely to be limited in scope but may indicate areas that could be explored more broadly. Administrative data on ICT form the basis of many of the Partnership's core indicators (Townsend and UNCTAD, 2011).

The current study found that these models and approaches are about the overall impacts of all possible forms and use of ICT not focused on IPDDS but it is relevant in selecting the items collected for measuring the effectiveness of IPDDS.

2.6 Challenges in Measuring the Impacts of ICT

There are several different ICTs, with different impacts in different contexts and countries. They include goods, such as mobile phone handsets, and services, such as mobile telecommunications services, which change rapidly over time. There are many ICTs are general-purpose technologies, which facilitate change and thereby have indirect impacts which are difficult to measure. It is difficult to determine what is meant by "impact". For example, a model proposed by OECD for ICT impacts (Figure 2.3) highlights the diversity of impacts, in terms of intensity, directness, scope, stage, timeframe and characterization (economic, social or environmental, positive or negative, intended or unintended, subjective or objective). Determining causality is difficult. There may be a demonstrable relationship and a positive correlation between dependent and independent variables. However, such a relationship cannot readily be proven to be causal. Many studies have categorized ICT impacts as economic, social or (less frequently) environmental. However, the picture is usually more complex than this. For example, while some direct impacts of ICT use can be described as economic, there may be indirect impacts that are social or environmental as done by Roztocki *et al.* (2019). In addition, direct impacts may be both economic and social, related through human capital, which is defined as "productive wealth embodied in labor, skills and knowledge".

2.7 Theories Related to Measuring the Effectiveness of IPDDS

2.7.1 Theories about innovation acceptance

Several theories about the acceptance of innovation are found in scientific literature. Such as the Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT), Theory of Planned Behavior (TPB), and Theory on Diffusion of Innovation (DoI). The first synthesized theory that explained what factors play a decisive role in the technology adoption process was created by Everett Rogers in 1962. To develop the theory, Rogers used a multi-disciplinary approach. He used sociology, communication, anthropology, and economics. The theory on DoI was the foundation of innovation acceptance and adoption research. The Theory of Planned Behavior and the Technology Acceptance Theory originated from the Theory of Reasoned Action (Venkatesh and Davis, 2007; Ajzen, 1985). The Theory explained the behavioral intention or, in the present case, the decision to start using technology due to two factors: information and silent beliefs. Information influences the attitude of a person toward a technology; silent beliefs are part of our subjective norms that could be, for example, general perceptions of a technology's usefulness. Davis (1989) suggested the Technology Acceptance Model in his dissertation in the area of economics first. The model explains the factors influencing the adoption of information technologies using psychological elements. Over time, this model was modified and enhanced several times, involving more determinants to increase its explanation potential. The UTAUT, presented by Venkatesh *et al.* (2003) represented the latest synthesized theory meant to explain the adoption of innovations.

2.7.2 Theory of Diffusion of Innovation (DoI)

DoI was the first interdisciplinary theory to explain the factors that influence the decision to accept innovation. It is possible to separate several important groups of factors that influence the adoption process: technology aspects and the channels employed to reach potential users. From the technological perspective, (Rogers, 1983) identified five important characteristics that new technology should have to be accepted by potential users: relative advantage, compatibility, complexity, trial ability and observability. Relative advantage is a user perspective of the benefits that a new technology provides. To measure relative advantage, not only economic indicators such as yield gain or cost reduction could be used but also intangible determinants such as satisfaction or convenience. "The greater the perceived relative advantage of an innovation, the more rapid its rate of adoption is going to be" (Rogers, 1983, p.15).

The next criterion is compatibility, which represents a degree of consistency with existing norms and values in the social system. The higher the compatibility is, the higher the odds that the innovation will be accepted. The level of perceived difficulty to understand or use the technology is defined as complexity. Rogers (1983) writes that generally, the innovations that are easy to understand are adopted rapidly, in comparison to the ones where one must acquire new skills or knowledge. Trial ability could be described as an opportunity to try the innovation on a certain, limited basis without a commitment to acquire it. This opportunity decreases the level of uncertainty about the technology. Uncertainty plays a crucial role in the innovation-decision process, because, as Rogers (1983) describes, "it is essentially an information-seeking and information-processing activity in which the individual is motivated to reduce uncertainty about the advantages and disadvantages of the innovation." The last criterion is observability, which is defined as a certain degree of result visibility. Some of the criteria suggested by Rogers (1983) can also be found in the TAM and TPB. The role of these five characteristics of innovation was tested in various studies in the field of agriculture. In the study about Cambodian farmers who should adopt rhizobium bacteria, Thar *et al.* (2021)

found out that only two factors out of five suggested by Rogers (1983) were significant: relative advantage and observability. In the study about the adoption of integrated pest management by cotton farmers in India, 99% of the variance could also be explained by two characteristics of the model: relative advantage and level of complexity (Peshin, 2013). These two innovations have different backgrounds: one represents a biological innovation and the other a technological one. This could mean that for the different types of innovation, one or the other characteristic can play a more important role, but the relative advantage, independent of the innovation, appears to be a significant criterion. A further important factor influencing the diffusion process is the channels that companies use to acquire new customers. According to Rogers (1983), there are two major important channels to spread information about an innovation: mass media and interpersonal channels. These channels play an important role in the decision-making process because the first step before a decision is made is gaining knowledge about the innovation. This is followed by persuasion, which is based on the individual's attitude toward the innovation. Rogers (1983) separated two groups of "knowers of innovation": earlier and later knowers. These types of knowers have different exposures to the knowledge sources and different levels of trust in different sources of knowledge.

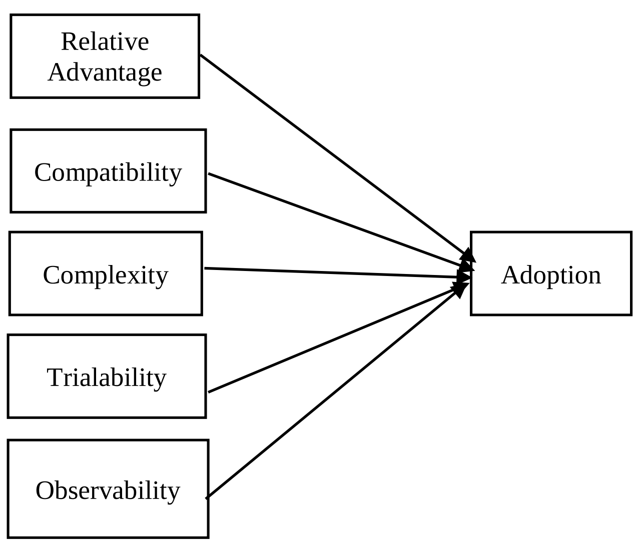

Fig. 2.5 Factors influencing the decision to adopt innovation (Rogers, 1983)

2.7.3 The D and M IS Success Model

The DeLone and McLean (D and M) model alternatively known as Information System (IS) success model guides future researchers on how to evaluate the success of an IT application or platform. The model grew up and matured for a long time with lots of experiments and modifications and updates. The updated D and M IS Success Model is presented in Figure 2.2. According to the updated D and M IS Success Model, quality has three major dimensions; "information quality," "systems quality." and "service quality." Each should be measured—or controlled for—separately because singularly or jointly, they will affect subsequent "use" and "user satisfaction" (Delone and McLean, 2003, p-23).

The effectiveness level is the effect of the information on the receiver. In the D and M IS Success Model, "systems quality" measures technical success; "information quality" measures semantic success; and "use, user satisfaction, individual impacts," and "organizational impacts" measure effectiveness success. Although this model is in the context of communication system effectiveness, it is related to IPDDS because of the presence of communication attributes of IPDDS. Delone and McLean (2003). recommended that "service quality" be added as an important dimension of IS success given the importance of IS support

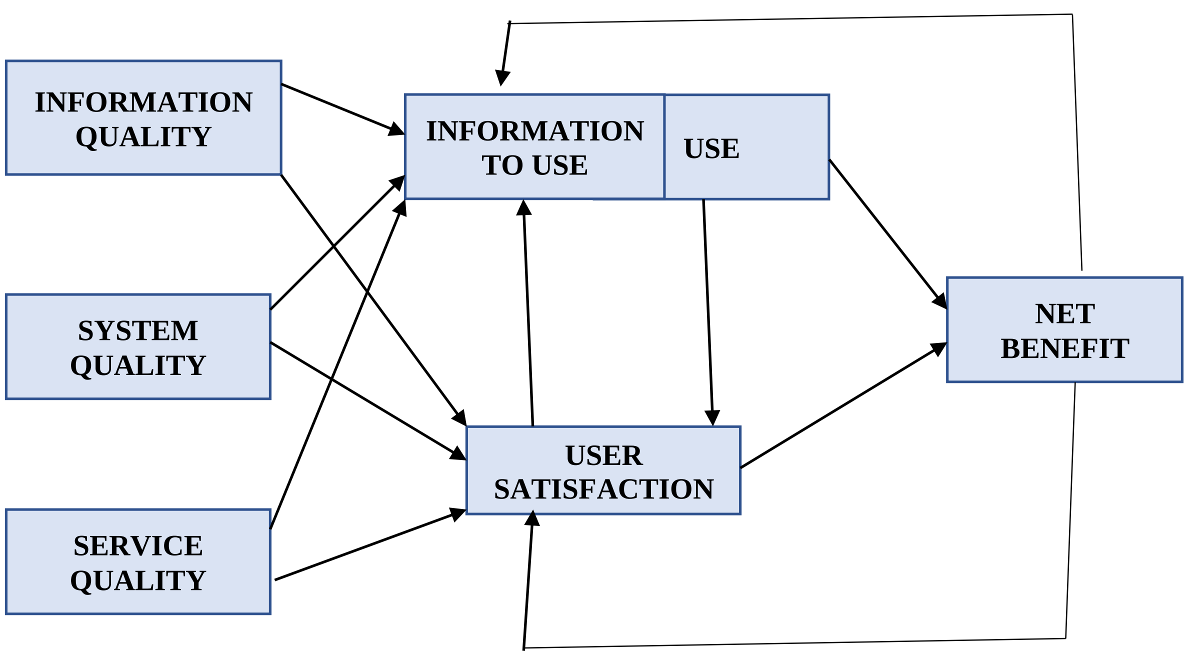

Fig.2.6 The updated D and M IS Success Model (Delone and McLean, 2003, p-24)

Among the theories discussed above updated D and M IS Success Model is mostly applicable for the current study. How the model is applied to develop a conceptual model is discussed in the next section. The DOI theory is useful for explaining the relationship among obtained benefits, obstacles faced in using IPDDS and perceived effectiveness of IPDDS. Other models and theories and approaches are useful for understanding the items of effectiveness, factors affecting the effectiveness and relationship among them.

2.8 Conceptual Framework of the Study

The effectiveness of IPPDDS is the study of how and to what extent IPDDS is satisfying the needs and demands of users. Several studies mentioned above suggested the factors affecting the effectiveness of ICT innovation. The current conceptual model of the study will explain how the factor of IPDDS user and IPDDS itself related collectively and related to each other. In the current study effectiveness of IPDDS is the main focus of the study and will be constituted by three sets of factors like personal characteristics- age, education, use of ICT, farming experience; socio-economic characteristics- crop farm size, annual crop production income, time saved; cost saved professional characteristics- knowledge on crop disease management, use of IPDDS, benefits obtained by using IPDDS, obstacles faced in using IPDDS. The effectiveness of IPDDS will be constituted through system properties like system accuracy, user-friendliness, off-line usability, device responsiveness, content quality and user satisfaction on the system. But the system properties will not be tested empirically in this study. The researcher believes that these factors will contribute to the focused variable. The study proposes a triangle of user, system and authority in increasing and maintaining the effectiveness of IPDDS. The proposed conceptual model of the study is based on the updated D and M IS Success Model and the DOI theory. Guidelines have been taken from other models and approaches. The updated D and M IS success model of Delone and McLean (2003) in which quality has been expressed in three major dimensions like information quality, systems quality and service quality assuming the measurement or control of each item separately, because singularly or jointly and they will affect the use and user satisfaction subsequently (Delone and McLean, 2003). Like proposed model expresses three groups of independent variables i.e. the personal characteristics (age, education, use of ICT, farming experience), socio-economic characteristics (crop farm size, annual crop production income, time saved, cost saved), and professional characteristics (knowledge on crop disease management, use of IPDDS, benefits obtained by using IPDDS, obstacles faced in using IPDDS) of the user. These independent variables constitute the effectiveness of IPDDS through system accuracy, off-line usability, user-friendliness, content quality, device responsiveness, and user satisfaction.

These variables have inter and intra relationships. To measure relative advantage prosed by (Rogers, 1983), not only economic indicators such as yield gain or cost reduction could be used but also intangible determinants such as satisfaction or convenience. “The greater the perceived relative advantage of an innovation, the more rapid its rate of adoption is going to be” (Rogers, 1983, p.15). A self-explanatory conceptual model of the study is presented in Figure 2.6.

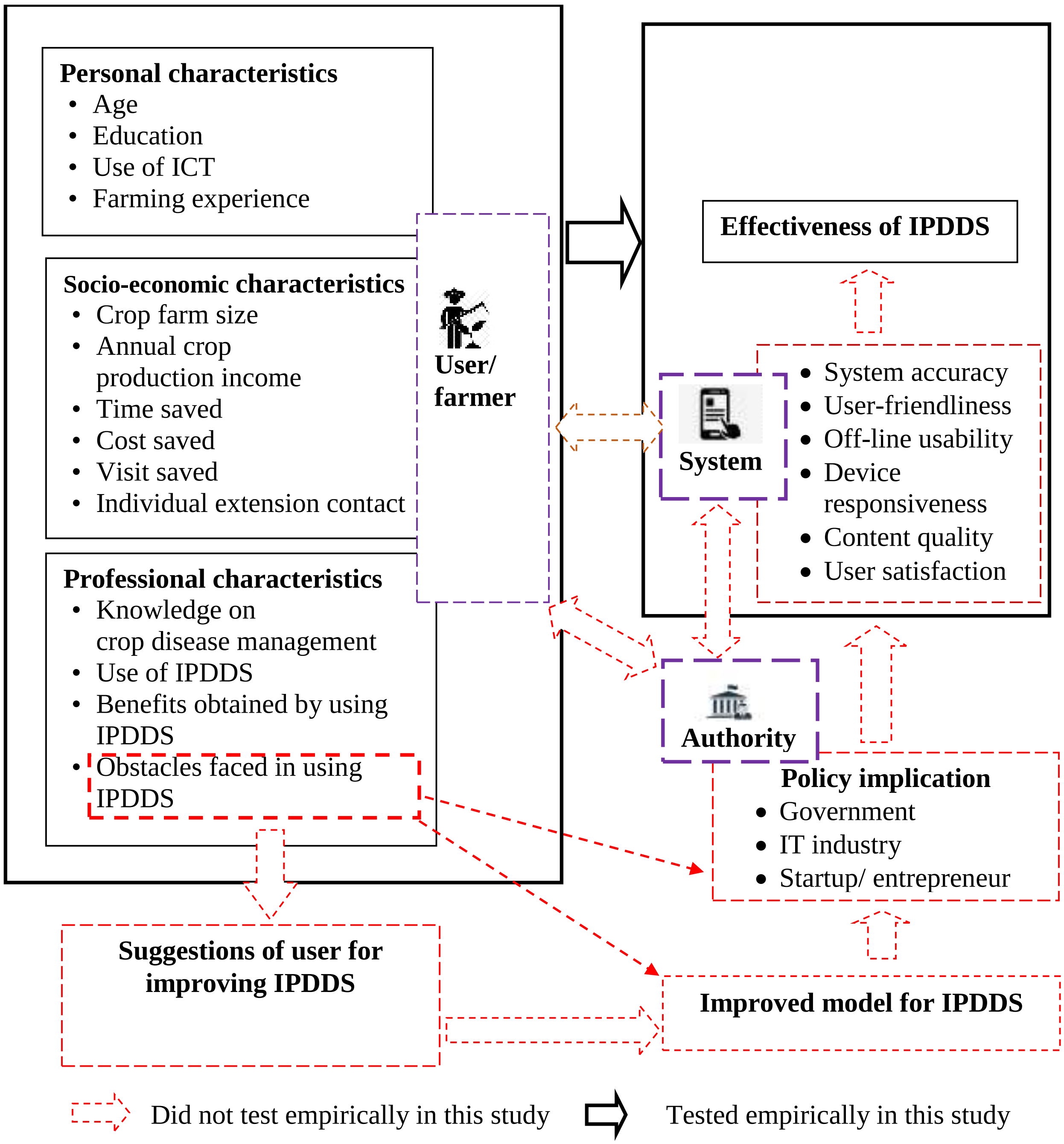

Fig 2.7 Conceptual Framework of the study

Supporting opinion of (Rogers, 1983), the proposed framework suggested benefit obtained by using IPDDS, obstacles faced in using IPDDS, cost, time and visit saved by users by using IPDDS to measure relative advantages of IPDDS. The framework suggested that the greater the perceived relative advantages of IPDDS, the greater the adoption or use of IPDDS and ultimately the greater the effectiveness of IPDDS. Acceding to the proposed model, users' characteristics like age, education, use of ICT, farming experience, crop farm size, annual crop production income, knowledge on crop disease management, use of IPDDS also contribute to the effectiveness of IPDDS will be constituted through system properties like system accuracy, user-friendliness, off-line usability, device responsiveness, content quality and user satisfaction on the system as suggested by (Delone and McLean, 2003). The proposed model can be termed as the "User-System quality model" since the model proposed both user and system quality in measuring the effectiveness of IPDDS. The model also proposed that from obstacles faced by users in using IPDDS, users will provide suggestions for mitigating the obstacles. Using the suggestions of the user, an improved model can be developed. This is a policy implication by the authority (government, IT industry, startup/ entrepreneur). The effectiveness of IPDDS can be improved through this process. There is an existence of a trio in the model among the user, authority, and system. The effectiveness of the system is constituted by/ dependent on the user (user's characteristics) via authority. Important additions of the proposed model are- an explanation of continuous improvement of the system and subsequent improvement in effectiveness which is dependent on the authority and policy implication.

CHAPTER 3
MATERIALS AND METHODS

Findings of research are dependent on the methodology researchers used in their research. The purpose of this Chapter was to describe the methodology used in conducting this study. The methodology gives a clear direction to researchers about their works and activities during the whole period of the study. This study intended to measure the effectiveness of IPDDS. Andress and Winterfeld (2014) defined effectiveness as the assessment of changes in system behaviour, capability, or operational environment that is tied to measuring the attainment of an end state, achievement of an objective, or creation of an effect. According to Lazer *et al.* (2021) measurement is the bridge connecting scientific motivations and data with insight and applications. The philosophical framework used from developing tools for collecting and analyzing data and interpretation is shown in Figure 3.1. Only the exception that no third-party data were used in this study.

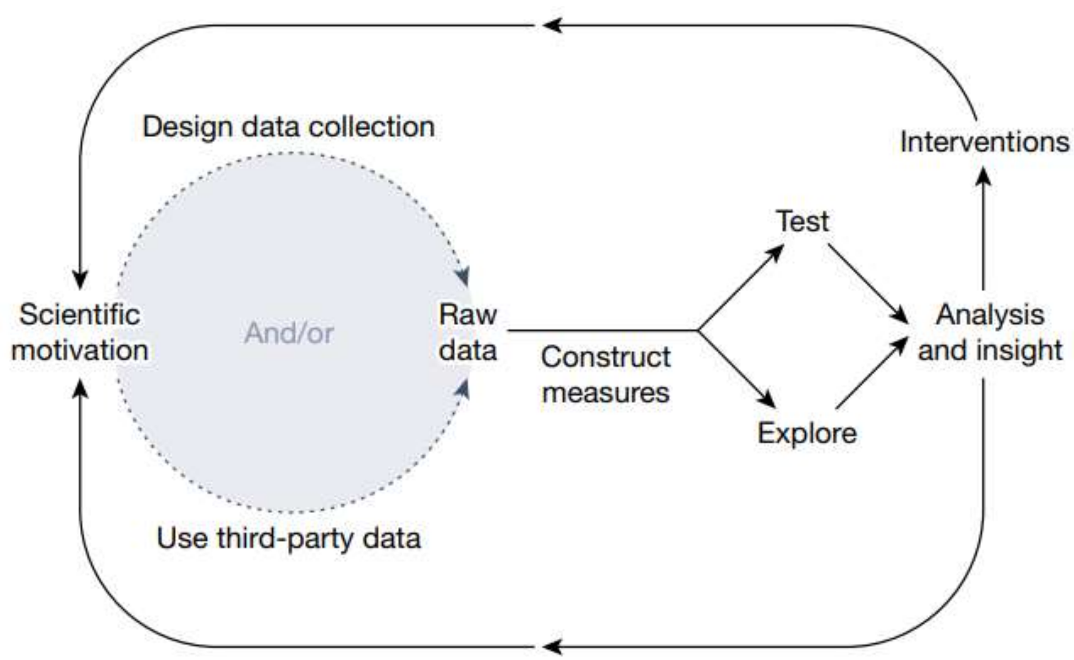

Figure 3.1 Measurement in social science (Lazer *et al.*, 2021)

3.1 Locale of the Study

Image-based Plant Disease Detection System (IPDDS) is used throughout Bangladesh. Therefore, the whole country was considered as the locale of the study.

3.2 Population of the Study

The population of IPDDS users in Bangladesh is unknown. The whole IPDDS users are spread throughout the country. Their locations are not known specifically. A list of 8911 registered users was collected from the Department of Agricultural Extension (DAE) which constituted the population of the study.

3.3 Sample Size and Sampling Procedure

The sample size was estimated to ensure the representation of the population. The size of the sample was determined by using a sample size calculator developed by Creative Research Systems (CRS, 2021) by taking 95% confidence level and 5 as a confidence interval. Thus the sample size was found as 370. It was examined by the researcher that this calculator gives the maximum sample size as 384 with a 95% confidence level and 5 as confidence interval in case of any population size above 222639. To ensure minimum error and maximum precision in research the sample size was taken as 384 for the study. The sampled population was selected randomly from the list. A reserve list of IPDDS users (about 10 % of the sample) was prepared for the interview. In case any user included in the original sample was not available despite of utmost effort during the collection of data, that list was used.

3.4 Data Collecting Instrument

A draft interview schedule was prepared considering the objectives of the study. Direct questions and appropriate scales were kept in the questionnaire to get the desired information. Data was collected from the respondents by telephone interviewing by the researcher himself using the interview schedule for the study. Telephone interviewing was used due to the scattered distribution of the IPDDS users all over the country and face-to-face interview was inconvenient. The draft interview schedule was pretested with 24 users. The final interview schedule was prepared after necessary addition, deletion, corrections and modification based on pre-test results. English version of the interview schedule is shown in Appendix I.

3.5 Procedure of Data Collection

Data were collected by the researcher himself through telephone interviewing of the selected sample users of IPDDS using the Bengali interview schedule. The data were collected during the period from May 01, 2021 to September 30, 2021. The researcher called the selected user respondent and interviewed after establishing a rapport with the respondent. In case of the non-availability of the sample users, the researcher paid make-up call to their convenient date and time. However, it was not possible to collect data from 30 selected users in the original sample due to their unavailability at the time of the interview despite several attempts to contact them. Therefore, the researcher had to collect data from 30 selected users of the reserve list.

3.6 Variables of the Study

A variable is a symbol to which numerals or values are assigned (Kerlinger and Lee, 1999 p-29). Ezekiel and Fox (1959) defined a variable as any measurable characteristics which can assume varying or different values in successive individual cases. The success of research to a considerable extent depends on the exact selection of the variables. There are two types of variables in any relationship study, viz. independent variable and dependent variable. An independent variable is the presumed cause of the dependent variable, the presumed effect (Kerlinger and Lee, 1999 p-30). A causal (Independent) variable is that factor that is manipulated by the researcher in his attempt to ascertain its relationship to an observed phenomenon. A dependent variable is that factor that appears, disappears or varies as the researcher introduces, removes or varies the causal variable (Townsend, 1953). In scientific research, the selection and measurement of variables constitute a significant task. Following this conception, the researcher reviewed literature, the developer's documents, users reviews in google play, websites and discussed with the Advisory Committee Members and related experts to widen this understanding about the natures and scopes of the variables relevant to this research. At last, the researcher had selected 14 Independent (Causal) variables and one dependent variable. The 14 selected characteristics of the users were considered as independent variables of the study and these were (a) personal characteristics - age, education, farming experience, use of ICT; (b) socio-economic and characteristics – crop farm size, annual crop production income, time saved, cost saved, visit saved and individual extension contact and (c) professional characteristics - knowledge on plant disease management, use of

IPDDS, obstacles faced in using IPDDS and benefits obtained by using IPDDS. Effectiveness IPDDS constituted the dependent variable of the study. The variables of the study were operationalized through direct questions, developing relevant scales by the researcher and scales developed by others as shown in Table 3.1.

Table 3.1 Summarized operationalization of the variables of the study with measuring unit

Variables	Measuring unit	Operationalization
Independent variables		
Personal characteristics		
1. Age	Actual years	Direct question
2. Education	Schooling years	Direct question
3. Use of ICT	Score	Scale developed for this study
4. Farming experience	Years	Direct question
Socio-economic characteristics		
5. Crop farm size	Decimal	Direct question
6. Annual crop production income	'000' BDT	Direct question
7. Time saved	Hours	Direct question
8. Cost saved	BDT	Direct question
9. Visit saved	Frequency	Direct question
10. Individual extension contact	Scores	Scale used by M. S. Ali (2008)with slightly modified for this study
Professional characteristics		
11. Knowledge on crop disease management	Scores	Scale developed with the concept of (Coombs, 1950) Bloom (1956) and used by M. S. Ali (2008), Rashid *et al.* (2016) and (U. Das *et al.*, 2020) with modification for the study
12. Use of IPDDS	Score	Scale developed for this study
14. Benefits obtained by using IPDDS	Score	Scale developed for this study
14. Obstacles faced in using IPDDS	Score	Scale developed for this study
Dependent variable		
Effectiveness of IPDDS	Scores	Scale developed with the aggregation of system accuracy, user-friendliness, off-line usability, device responsiveness, content quality, and user satisfaction after case study and pre-test

3.7 Measurement of Independent Variables

It was pertinent to follow a methodological procedure for measuring the selected variables to conduct the study in accordance with the objectives. The procedures for measuring the independent (causal) variables are described below:

3.7.1 Personal characteristics

3.7.1.1 Age

Age of respondents was measured in terms of years from their birth to the time of interview. A score of one (1) was assigned for each year of age. Question regarding this variable appears in item no. 1 in the interview schedule (Appendix I). M. F. Hasan *et al.* (2020) followed this procedure for measuring age.

3.7.1.2 Education

Education was measured in terms of one's year of successful schooling. One (1) score was given for passing each year in an educational institution. M. S. Ali (2008)) and M. F. Hasan *et al.* (2020) followed this procedure for measuring education score. For example, if the respondent passed the S.S.C. examination, his education score was given as 10; if respondent passed the final examination of class Nine (IX), his education scores was given as 9. A score of 0.5 (half) was given to that respondent who could sign his/her name only. A score of one (1) was assigned for those respondent who learnt only reading and writing on simple basis from the adult learning center (M. S. Ali, 2008). Question regarding this variable appears in the item no. 2 in the interview schedule (Appendix I).

3.7.1.3 Use of ICT

Use of ICT refers to the frequency of ICTs used by a user. Use of ICT for agricultural purpose refers to the extent of ICTs use by respondents for farm-related activities while the non-farm-related purposes is referred to as general purpose. A scale was developed for the study considering frequency of use of simple cell phone, smartphone and laptop or desktop off-line and on-line following the scale used by Rashid *et al.* (2016). Question regarding this variable appears in the item no. 3 in the interview schedule (Appendix I). Thus, the possible range of score use of ICT of a respondent could be from 0 to 8 while ‘0’ indicating no use of ICT and ‘8’ indicating highest use of ICT. The scoring system of use of ICT was as follows:

Sl. No.	Items	Maximum score for use of ICT			
		Regular	Occasional	Rare	Not at all
1	Mobile device - offline	3	2	1	0
2	Mobile device - online	4	3	2	0
3	Computer device - offline	5	4	3	0
4	Computer device - online	6	5	4	0
5	Computer and Mobile device - offline	7	6	5	0
6	Computer and Mobile device - online	8	7	6	0

3.7.1.4 Farming Experience

Farming experience of the respondent was measured by the number of years a respondent engaged in crop cultivation. The measurement included from the year of starting of first crop cultivation till the year of data collection. A score of one (1) was assigned for each year of farming experience. M. F. Hasan *et al.* (2020) used this type of measurement. Question regarding this variable appears in the item no. 4 in the interview schedule (Appendix I).

3.7.2 Socio-economic characteristics

3.7.2.1 Crop farm size

Crop farm size refers to the total land of the respondent under crop production. It included own land under own cultivation and land taken from others as lease or share basis. Farm size was measured in decimal. A score of one was assigned for one decimal of land. Rashid *et al.* (2016) used this types of scoring system. Questions regarding this variable appears in the item no. 5 in the interview schedule (Appendix I).

3.7.2.2 Annual crop production income

Annual crop production income referred to the total earnings of a respondent from crop production sources (cereals, fruits, vegetables etc.) in las year. Annual crop production income was expressed in '000' BDT i.e. One (1) score was given for BDT 1000 annual crop production income. For example, a score of 45 was given to a respondent whose annual crop production income was BDT 45,000. Questions regarding this variable appears in the item no. 6 in the interview schedule (Appendix I).

3.7.2.3 Time saved

Time saved refers to the amount of time saved by the respondent by using IPDDS in getting plant disease-related service. It was measured in hours. Respondents were asked to provide information on the amount of time they had to spent for getting plant disease-related service without using IPDDS and using IPDDS. The difference was considered as the score of time saved. Questions regarding this variable appears in the item no. 7 in the interview schedule (Appendix I).

3.7.2.4 Cost saved

The cost saved refers to the amount of cost saved by the respondent by using IPDDS in getting plant disease-related service. It was measured in BDT. Respondents were asked to provide information on the amount of cost they had to spend for getting plant disease-related service without using IPDDS and using IPDDS. The difference was considered as the score of the cost saved. Questions regarding this variable appears in the item no. 8 in the interview schedule (Appendix I).

3.7.2.5 Visit saved

Visit saved refers to the frequency of visit saved by the respondent by using IPDDS in getting plant disease-related service. It was measured in frequency. Respondents were asked to provide information on the frequency of visit needed for getting plant disease-related service without using IPDDS and using IPDDS. The difference was considered as the score of visit saved. Questions regarding this variable appears in the item no. 9 in the interview schedule (Appendix I).

3.7.2.6 Individual extension contact

Individual extension contact of a respondent was measured by the extent of contact with 5 selected individual agricultural extension media. A scale was developed arranging the weights as 3, 2, 1 and 0 for the responses for regularly, occasionally, rare and not at all contact with this agricultural extension related media respectively. Scale developed by M. S. Ali (2008) for measuring extension contact was used with slight modified by the present researcher for measuring extension contact of the respondents. Logical frequencies of contact were assigned for each type of responses for each item as mentioned in the item no. 10 of the interview schedule (Appendix I).

Finally, individual extension contact score of a user was computed by summing up all the scores for contact with 5 types of selected individual extension media by that respondent. Thus, extension contact score of a respondent could range from 0 to 15 while ‘0’ indicating no individual extension contact and ‘15’ indicating the highest individual extension contact.

3.7.3 Professional characteristics

3.7.3.1 Knowledge on plant disease management

Knowledge as defined in this study included ‘those behavior and test situations which emphasized the remembering either by recognition or recall of ideas, material or phenomenon’ (Bloom, 1956). This variable indicated the extent of knowledge on plant disease management of the respondents at the time of interview as evident from their responses to a set of questions logically and scientifically prepared for this purpose. The steps followed in developing the scale for knowledge test for this study are discussed below:

Collection of items: The content of knowledge test is composed of questions called items. Items for the test were collected from different sources, such as, literatures; documents on IPDDS, agricultural scientists of agronomy, horticulture, soil science, agricultural chemistry, entomology, plant pathology, agro-forestry, environmental science, and agricultural extension education of home and abroad; extension personnel; NGO personnel; progressive users, findings of case study and researcher’s own experience. The questions were designed to test the knowledge on plant disease management of the users. The items were collected and prepared in relation to plant disease management. Initially, 36 items were collected which appeared to be relevant.

Screening of items: On the basis of Bloom’s (1956) taxonomy as devised by Anderson *et al.* (2001), 24 questions by taking 4 from each of remembering, understanding, applying, analyzing, evaluating and creating on plant disease management were selected out of initially collected 36 questions for pre-test (Appendix III).

Item analysis: The item analysis of a knowledge test usually yields two kinds of information, that is, item difficulty and item discrimination. The index of item difficulty indicates how difficult an item is, whereas, the index of discrimination explores the extent to which an item discriminates the well-informed users from poorly informed ones.

The items were analyzed on the basis of pre-test data obtained by administering to 24 users. The users for administering the items were randomly selected and were different from the sample users of the present study. Nevertheless, these 24 users were representative of the total population on the basis of which the final study was conducted. Each of the 24 items had four alternative choices of answers including one right answer. Each one of the 24 respondents, to whom the test was administered, was given one (1) score for right answer and zero (0) score for 'wrong' or no answer with respect to each item. The total number of right answers given by the respondent out of 24 items was the knowledge score secured by him. The maximum score was obviously 24 which could be scored when all the 24 items were answered correctly. The scores of correct answers against each item of all the 24 respondents were also calculated which are presented in Appendix IV.

Calculation of difficulty index: Johari *et al.* (2011) used the following formula to calculate the difficulty index of an item:

$$Pi = \frac{ni}{Ni} x100$$

Where,

Pi = Difficulty index in percentage of ith item
ni = Number of users giving correct answer to ith item
Ni = Total number of users to whom ith item was administered, i.e. 24 in the present study

M. S. Ali (2008) explained the concept differently. According to him, difficulty index of an item indicates how difficult an item is. But the above formula is fully opposite to the concept of difficulty index. Actually, the value of Pi obtained from the above formula indicates how easy an item is. Because it is measured by the percentage of number of users giving correct answer to ith item and total number of users to whom ith item was administered. It might be termed as easiness index.

However, under the above circumstances the researcher of the present study with slight modification determined difficulty (Pi) index by the following revised formula as suggested by M. S. Ali (2008):

$$Pi = \frac{ni}{Ni} x100$$

Where,

Pi = Difficulty index in percentage of ith item
ni = Number of users giving incorrect answer to ith item
Ni = Total number of users to whom ith item was administered,
i.e. 24 in the present study

All parts of the above two formulae are same, only the meaning of ni is different. However, in the modified formula, the higher was the difficulty index of an item, the more difficult the item was. Therefore, the difficulty indices of all the 24 items were calculated by the formula revised by M. S. Ali (2008). It was ensured that very difficult and very easy items were eliminated. The underlying assumption in the statistics of item difficulty was that the difficulty was linearly related to the level of an individual's knowledge on plant disease management. When a respondent gave correct answer to an item, it was assumed, as Coombs (1950) described, that the item was less difficult than his ability to cope with it. The difficulty indices have been presented in Appendix IV.

Calculation of discrimination index: Brennan (1972) expressed discrimination index (DI) as one of the measures of item effectiveness typically calculated by test evaluators, he exemplified it as a measure of comparison between the number of student in an upper group who get an item correct and the number of student in an lower group who get an item correct (Brennan, 1972 p-289). The discrimination index can be computed by calculating the phi-coefficient as formulated by Perry and Michael (1952). However, Mehta (1958) developed $E^{1/3}$ method to find out item discrimination emphasizing that this method was analogous to, and hence, a convenient substitute for phi-coefficient. The method developed by Mehta (1958) was used by U. Das *et al.* (2020), M. S. Ali (2008).

Like M. S. Ali (2008), the present researcher computed the total scores against all the correct responses of each user. The users were then arranged in descending order of total scores obtained by them. Then those users were divided into 6 equal groups each having 4 users as the total number of users in the sample for item analysis was 24. These groups were G_1, G_2, G_3, G_4, G_5 and G_6 respectively. For determination of discrimination index the middle two groups, i.e. G_3, and G_4 were eliminated and kept only extreme four groups with high (G_1 and G_2) and low (G_5 and G_6) scores. Then discrimination index of each item was determined by using the following formula:

$$E^{1/3} = \frac{(S_1 + S_2) - (S_5 + S_6)}{N/3}$$

Where, S_1, S_2, S_3, S_4, S_5 and S_6 were the frequencies of the correct answer for each item in G_1, G_2, G_3, G_4, G_5 and G_6 groups respectively and N was the total number of users in the sample of item analysis.

The discrimination indices of all the 24 items were calculated by the procedure mentioned above and are presented in Appendix IV.

Final selection of items: Two criteria namely, item difficulty index and item discrimination index were considered for the selection of items in the final format of the knowledge on plant disease management test. Items having extreme high or extremely low value of difficulty index and discrimination index were eliminated.

In the present study items with difficulty index values ranging from 16.67 to 83.33 (while observed values ranging from 8.33 to 95.83) and discrimination index ranging from 0.125 to 0.875 (while observed value ranging from 0 to 1) were included in the final format of knowledge on plant disease management scale. In this way, 12 items by taking two (2) from each of remembering, understanding, applying, analyzing, evaluating and creating which fulfilled both the criteria and these items were selected for the final format of the Knowledge on plant disease management scale.

Scoring system: Each item had four alternative answers including one right answer. The respondents were asked to choose the right answer for each item. One (1) score was given for right answer and zero (0) for wrong or no answer against each item. The summation of such scores for all the responses of a user was the knowledge on plant disease management score of that user. Thus, the possible range of score on knowledge on plant disease management was 0 to12 while indicated very low knowledge and 12 indicated very high knowledge on plant disease management.

3.6.3.2 Use of IPDDS

It refers to the frequency and type of IPDDS used by the users for detecting diseases of their crop. A scale was developed for the study considering frequency and type of IPDDS. Where score of 0, 1, 2 and 3 were assigned for not at all, seldom, occasional and regular use of each type of IPDDS a user use respectively. Thus the possible range of use of IPDDS was 0 – 9, where '0' indicated no use and '9' indicated highest use. Question regarding this variable appears in the item no. 12 in the interview schedule (Appendix I).

Use Index: Use Index (UI) of each types of IPDDS was measured by adding the scores of all the respondents against that type by using the following formula:

$UI = f_r x3 + f_o x2 + f_s x_1 + f_n x0$

Where,

UI = Use Index

F_r = Frequency of respondents use regularly

F_o = Frequency of respondents use occasionally

F_s = Frequency of respondents use seldom

f_n = Frequency of respondents not at all use

Thus, the range of UI of the IPDDS could be 0-3x384 i.e. 0-1152, where '0' indicated not at all use and '1152' indicated the highest use of the IPDDS. Karim *et al.* (2020) used similar formula for calculating role index to determine the use and role of mobile phone for information services in agricultural activities.

Standardized Use Index: Standardized Use Index (SUI) was measured by using the following formula for each item:

$$SUI = \frac{\text{UI of IPDDS}}{\text{Possible highest UI}} x100$$

Here possible highest UI was 1152.

Thus, the possible range of SUI of the IPDDS was 0-100, where '0' indicated no use and '100' indicated highest use of IPDDS. Based on the descending order of SUI rank order of the IPDDS was made to understand the use of IPDDS.

3.6.3.3 Benefits obtained by using IPDDS

Benefits obtained by using IPDDS are the extent of benefits obtained by the users by using IPDDS for detecting diseases of their crop. A total of 9 items of benefits obtained by using IPDDS were collected through consultation with relevant expert. A scale was developed for the study. where 0,1, 2 and 3 were assigned for obtaining no, low, moderate and high benefit against each item of using IPDDS. Finally, scores of benefits obtained by respondents by using IPDDS was determined by adding all the scores against all the items. Thus, benefit score of the respondents ranged 0 - 27. Where '0' indicated no benefit and '30' indicated highest benefits of the respondent. Question regarding this variable appears in the item no. 13 in the interview schedule (Appendix I).

Benefit Index: Benefit Index (BI) of an item was measured by adding the scores of all the respondents against that item by using the following formula:

$BI = f_h x3 + f_m x2 + f_l x1 + f_n x0$

Where,

BI = Benefit Index

f_h = Frequency of respondents obtained high benefit

f_m = Frequency of respondents obtained moderate benefit

f_l = Frequency of respondents obtained low benefit

f_n = Frequency of respondents obtained no benefit

Standardized Benefit Index: Standardized Benefit Index (SBI) was measured by using the following formula for each item:

$$\text{Standardized benefit index (SBI)} = \frac{\text{Computed benefit index}}{\text{Possible highest benefit index}} \text{x}100$$

Thus the range of SBI of the items was 0-100, where '0' indicated no benefits and '100' indicated highest benefits. Based on the descending order of SBI rank order of the items were made to understand the importance of the items.

3.6.3.4 Obstacles faced in using IPDDS

Obstacles faced in using IPDDS refers to the extent of obstacles faced by the users during using IPDDS for detecting diseases of their crop. A total of 10 obstacles in using IPDDS were collected through consultation with relevant expert. A scale was developed for measuring the obstacles faced in using IPDDS. where 0,1, 2 and 3 were assigned for facing no, low, moderate and high obstacles against each item of using IPDDS. Finally, the score of obstacles faced by a respondent in using IPDDS was determined by adding all the scores. Thus, obstacle faced score of the respondent ranged from 0-30. Where '0' indicated no obstacle and '30' indicated highest obstacles of the respondent in using IPDDS. M. F. Hasan *et al.* (2020) used a similar scale in measuring constrains faced by user in using ICTs. Question regarding this variable appears in the item no. 14 in the interview schedule (Appendix I).

Obstacle Index: Obstacle Index (OI) of an item was measured by adding the scores of all the respondents against that item by using the following formula:

$OI = f_h x3 + f_m x2 + f_l x1 + f_n x0$

Where,

OI = Obstacle Index

f_h = Frequency of respondents facing high obstacle

f_m = Frequency of respondents facing moderate obstacle

f_l = Frequency of respondents facing low obstacle

f_n = Frequency of respondents facing no obstacle

Thus, the obstacle faced score of the respondent could be ranged 0-30. Where '0' indicated no obstacle and '30' indicated the highest obstacles of the respondent. Attempts were taken to seek suggestion from the respondents against each obstacle to mitigate them which helped to prepared the improved model for IPDDS. M. F. Hasan *et al.* (2020) computed the Constraint Faced Index (CFI) using a similar formula.

Standardized Obstacle Index: Standardized Obstacle Index (SOI) was measured by using the following formula for each item:

$$\text{Standardized Obstacle Index (SOI)} = \frac{\text{Computed obstacle index}}{\text{Possible highest obstacle index}} \text{x}100$$

Thus, the range of SOI of the items could be 0-100, where '0' indicated no obstacles and '100' indicated the highest obstacles. Based on the descending order of SOI rank order of the item (among the dimension and among all the items) were made to understand the importance of the items.

3.8 Measurement of Effectiveness of IPDDS (Dependent Variable)

3.8.1 Development of a scale for measuring the effectiveness of IPDDS

This study adapted the method from M. S. Ali (2008). A detailed outline of the method is diagrammatically presented in Figure 3.1.

Initial collection of effectiveness items: This study adopted a rigorous method of scale development and data collection such as literature review, developers' interviews, users' reviews. This search primarily yielded 32 items. Then 32 items were primarily selected in consultation with the advisory committee.

Selection of items by computing t-value based on pre-test results: The primarily selected (32) items were administered to 24 users. The users for administering the items were randomly selected and were different from the sample users of the present study. They were asked to indicate their perception of effectiveness of IPDDS by giving score of 3,2,1 and 0 for indicating highly effective, moderately effective, low effective, and not effective at all respectively. Thus, the possible score of the effectiveness scale ranged from 0-96, while '0' indicates the lowest effectiveness and '96' indicates the highest effectiveness of using IPDDS. Respondents were also requested to provide suggestions or give comments regarding the clarity of the questionnaire items.

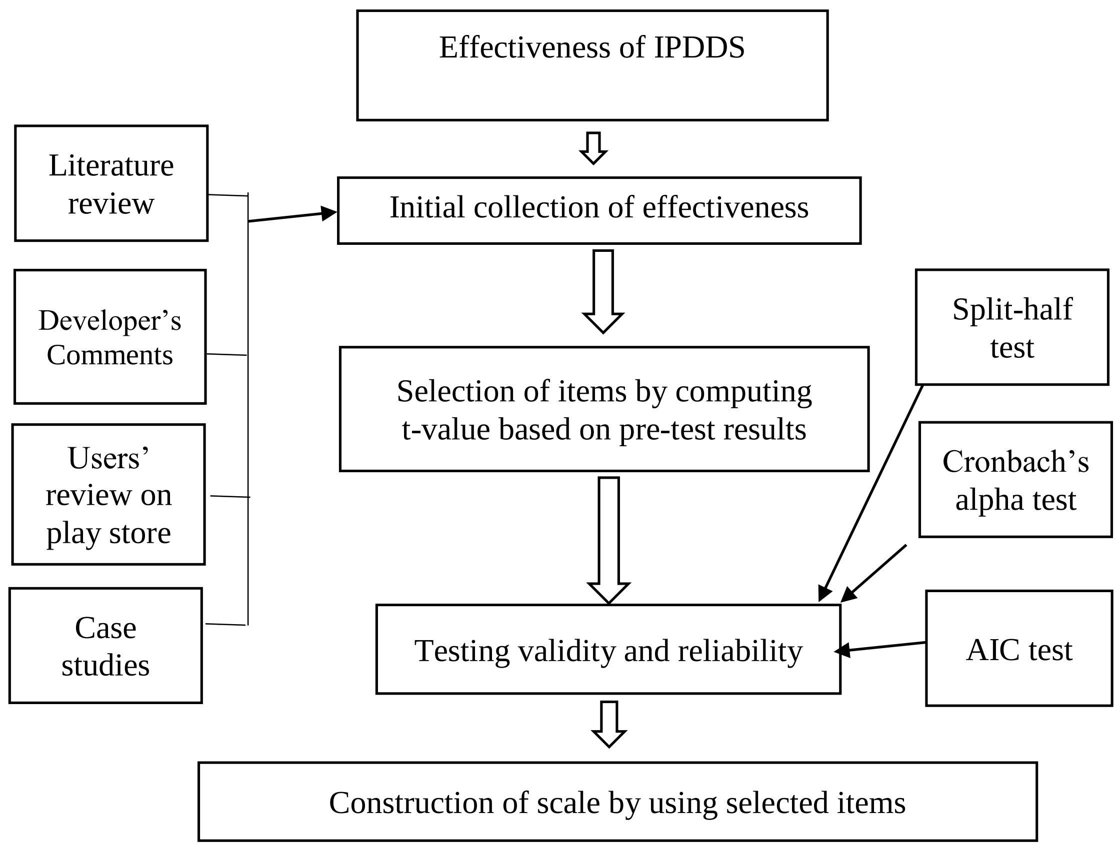

Fig. 3.2 Summarized operational steps involved in construction of scale to measure effectiveness of IPDDS

Analysis of effectiveness items as per Likert's Technique of Summated Ratings: Selected 32 items were analyzed using Likert's Technique of Summated Ratings for the final selection of items to measure the effectiveness of using IPDDS. Analysis of items consisted of the frequency distribution of scores based upon the responses to all pretest items. The top 25 percent of the respondents with the highest scores (high group) and the bottom 25 percent of the respondents with the lowest scores (low group) were used as criterion groups to evaluate the individual item. The critical ratio (t-value) was calculated by using the following formula as suggested by Edwards (1957):

$$t = \frac{\overline{X_H} - \overline{X_L}}{\sqrt{\frac{{S_H}^2}{n_H} + \frac{{S_L}^2}{n_L}}}$$

Where,

$\overline{X_H}$= The mean score on a given statement for the high group

$\overline{X_L}$= The mean score on a given statement for the low group

${S_H}^2$= The variance of the distribution of responses of the high group to the statement

${S_L}^2$ = The variance of the distribution of responses of the low group to the statement

n_H = The number of subjects in the high group

n_L = The number of subject in the low group

As n_H= n_L= n (number of subjects/respondents in each group) and the same percentages of the total number of subjects for the high and low groups were selected, the formula was reformed as:

$$t = \frac{\bar{X}_H - \bar{X}_L}{\sqrt{\frac{\sum(X_H - \bar{X}_H)^2 + \sum(X_L - \bar{X}_L)^2}{n(n-1)}}}$$

Where,

$$\sum(X_H - \bar{X}_H)^2 = \sum {X_H}^2 - \frac{(\sum X_H)^2}{n}$$

And

$$\sum(X_L - \bar{X}_L)^2 = \sum {X_L}^2 - \frac{(\sum \boldsymbol{X_L})^2}{\boldsymbol{n}}$$

$\sum {X_H}^2$ = Sum of the squares of the individual scores in high group

$\Sigma {X_L}^2$= Sum of the squares of the individual scores in the low group

The value of 't' was a measure of the extent to which a given items differentiate between the high and low groups. As suggested by Edwards (1957), there is a thumb rule of rejecting items with 't' values <1.75. Usually, a t-value equal to or greater than 1.75 indicates that the average responses of the high and low groups to an item differ significantly. Finally, t-values of all the items were determined. The items having 't' values ≥ 1.75 were finally selected for scale. Thus, 22 items of effectiveness of IPDDS out of 32 were selected for the final scale which may be seen in Appendix V.

3.8.2 Testing validity and reliability

The validity and reliability of a scale are very important issues to be ensured during developing the scale. The content validity was ensured in the process of constructing the scale. Based on pre-test results, items having t-value of $\geq$ 1.75 were selected for the final scale. Again, the validity of items was measured by the relationships between the score of each individual item and the total score against all the items. The coefficient of correlations between the scores of individual item and overall score against all the items were significant at 0.000 to 0.05 level with 22 degrees of freedom for all the item. On the basis of the procedure followed, it can be assumed that the scale had content validity.

Cronbach's alpha and Average Inter-Item Correlation (AIC) of the items were determined. Cronbach's alpha value of $\geq$ 0.7 indicates strong reliability (George and Mallery, 2006), (Tavakol and Dennick, 2011) and AIC of $\geq$ 0.15 indicates that the items on the scale are assessing the same content (Cohen *et al.*, 2012). It was found that the Cronbach's alpha of the items was 0.936 which was greater than 0.7. Chin *et al.* (1988) test the overall reliability of items using Cronbach's alpha and they found the value 0.939 in development of a tool measuring user satisfaction of the human-computer interface. They interpreted that the questionnaire had maintained a high degree of reliability. Again AIC of 22 items were 0.468 which was greater than 0.15. Therefore, it can be said that the internal consistency reliability of the items was strong. It means that the scale constructed by using the above procedures was reliable. Again, the reliability of the scale was measured by split-half method. All the 22 items were divided into two halves, one with 11 odd-numbered items and the other with 11 even-numbered items. The coefficient of correlation between the two sets of scores of the users against the odd-numbered items and even-numbered items was computed and the value was found to be strongly significant (0.937) at 0.000 level with 22 degrees of freedom. The reliability co-efficient, thus obtained indicated that the 'internal consistency' of the items was quite high.

3.8.3 Construction of scale by using selected items

A total of 22 items (having t-value $\geq$ 1.75) constituted the scale for measuring the effectiveness of IPDDS. These were to administered to the respondent users by assigning the scores as 3, 2, 1 and 0 for ‘highly effective’, ‘moderately effective’, ‘low effective’ and ‘not at all effective’ respectively against each item. Total score of a respondent was obtained by adding all the scores against all the items of the respondent. Thus, the effectiveness of IPDDS score of the respondents could range from 0-66, where ‘0’ indicates not at all effective and ‘66’ indicates highly effective.

3.8.4 Measuring Standardized Effectiveness Index (SEI)

Effectiveness Index: Effectiveness Index (EI) of an item was measured by adding the scores of all the respondents against that item by using the following formula:

$$\mathbf{EI = f_h x3 + f_m x2 + f_l x1 + f_n x0}$$

Where,

EI = Effectiveness Index

f_h = Frequency of respondents perceived highly effective

f_m = Frequency of respondents perceived moderately effective

f_l = Frequency of respondents perceived low effective

f_n = Frequency of respondents perceived not at all effective

Thus, the range of EI of the items could be 0-3x384 i.e. 0-1152, where, ‘0’ indicated not at all effective and ‘1152’ indicated highest effectiveness of the item. Salam and Khan (2020) used similar way for calculating index score of a 5 point Likerd scale.

3.7.2.2 Standardized Effectiveness Index (SEI)

Standardized Effectiveness Index (SEI) was measured by using the following formula for each item:

$$\text{Standardized effectivness index (SEI)} = \frac{\text{Computed effectiveness index}}{\text{Possible highest effectiveness index}} \text{x} 100$$

Thus, the range of SEI of the items could range 0-100, where ‘0’ indicated no effectiveness and ‘100’ indicated highest effectiveness. Based on the descending order of SEI rank order of the item (among the dimension and among all the items) were made to understand the importance of the items.

Average Standardized Effectiveness Index (ASEI): Average Standardized Effectiveness Index (ASEI) was measured by using the following formula for each item:

$$\text{ASEI} = \frac{\text{Sum of SEI of all the items of the dimension}}{\text{No of items of the dimension}}$$

Where, ASEI = Average Standardized Effectiveness Index

Based on the descending order of ASEI, rank order of the dimensions of effectiveness was made.

3.9 Statement of Hypothesis

According to Kerlinger (1973), a hypothesis is a conjectural statement of the relation between two or more variables. Hypothesis are always in declarative sentence form and they relate either generally or specifically variables to sentence form and they relate either generally or specifically variables to variables. The hypothesis may be broadly divided into two categories, namely, research hypothesis and null hypothesis.

3.8.1 Research hypothesis

In the light of the objectives of the study and variables selected, the following research hypotheses was formulated to test them. The research hypotheses were stated in positive form; the hypotheses were as follows:

"Each of the fourteen (14) selected characteristics of the respondents have significant contribution/effect to/on the effectiveness of IPDDS".

The hypotheses can be extended as each of the fourteen (14) selected characteristics of the respondents contributes to the effectiveness of IPDDS either positively or negatively.

3.8.2 Null hypothesis

The aforesaid research hypothesis was converted into a null hypothesis for testing the conceptual model of the study. The major null hypothesis formulated for testing the conceptual model of the study is presented below:

"There is no significant contribution/effect of the fourteen (14) selected characteristics of the respondents to/on the effectiveness of IPDDS".

3.10 Data Processing

3.10.1 Editing

The collected raw data were examined thoroughly to detect errors and omissions. As a matter of fact, the researcher made a careful scrutiny of the completed interview schedule to make sure that necessary data were entered as complete as possible and well arranged to facilitate coding and tabulation. Very minor mistakes were detected by doing this, which were corrected promptly.

3.10.2 Coding and tabulation

Having consulted with the research Advisory Committee Members, the researcher prepared a detailed coding plan. In case of qualitative data, suitable scoring techniques were followed by putting proper weightage against each of the traits to transform the data into quantitative forms. These were then tabulated in accordance with the objective of the study.

3.10.3 Categorization of data

Following coding operation, the collected raw data as well as the respondents were classified into various categories to facilitate the description of the independent and dependent variables. These categories were developed for each of the variables by considering the nature of distribution of the data and extensive literature review. The procedures for categorization have been discussed while describing the variables in chapter 4.

3.10.4 Statistical analysis

IBM SPSS 20 was used for data analysis. Descriptive statistical measures including number and percentage distribution, range, mean, standard deviation and co-efficient of variance were used for describing both the independent and dependent variables. Rank order was made whenever necessary. Tables were also used in presenting data for the clarity of understanding.

Initially, Spearman's rank correlation was run to determine the relationship of each of the selected characteristics of the users with the effectiveness of IPDDS. Full model regression analysis was also done. Due to misleading results from multi-collinearity, stepwise multiple regression was used by involving significant independent variables after the correlation test to find out the contribution of the independent variables to the dependent variable. Finally, path analysis was done to find out the indirect effects of the independent variables separately on the dependent variable. A five percent (0.05) level of probability was used as the basis for rejection of any null hypothesis throughout the study. Co-efficient values significant at 0.05 level are indicated by one asterisk (*), and that at 0.01 level by two asterisks (**) and at 0.001 level or above by three asterisks (***). For determining comparative effectiveness of the items, rank order was made based on the descending order of the Standardized Effectiveness Index (SEI), Use Index (UI) and Obstacle Faced Index (OFI), and Benefit Index (BI) respectively. Khalak *et al.* (2018) used similar method to study factors associated with farmers' extent of access to ICT based media. Suggestions from the respondent to mitigate the obstacles were analyzed using word mapping online software (Zygomatic, 2021).

CHAPTER 4
RESULTS AND DISCUSSION

This Chapter intended to discuss the findings of the research. According to the objectives of the study, the findings of the study are discussed in the following heads:

- ✓ Purpose of using IPDDS, profession, gender, and geographical regions of IPDDS users
- ✓ Effectiveness of IPDDS as perceived by the users
- ✓ Characteristics of the IPDDS users
- ✓ Contribution and effects of the selected characteristics of the users to/on their perceived effectiveness of the IPDDS
- ✓ Benefits obtained and obstacles faced in using IPDDS
- ✓ Development of an improved model of IPDDS

4.1 Purpose of Using IPDDS, Profession, Gender, and Geographical Regions of IPDDS Users

4.1.1 Purpose of Using IPDDS,

Peoples of Bangladesh mainly use IPDDS for detecting plant diseases. But the users' specific purposes are varied as: own farming purpose, farm supporting purpose, service purpose, business purpose, roof top gardening purpose, service and farming purpose, business and farming purpose, and study purpose. The distribution of the users of IPDDS according to the use purpose is shown in Figure 4.1.1. The figure showed that according to purpose of use, user of IPDDS in percent own farming purpose (44%) ranked first followed by farm supporting purpose (34%), service and farming purpose (6.8%), business and farming purpose (4.4%), service purpose (3.6%), roof top gardening purpose (3.2%), study purpose (2.0%) and business purpose (2.0%). The findings indicate that IPDDS is mostly used in own farming purpose. Hassan *et al.* (2008) studied the use of Information and Communication Technology

(ICT) among agro-based entrepreneurs in Malaysia and revealed that market information, production input, advice, loan service, agriculture land, post-harvest, record saving, entrepreneurs information sharing, disease control, output processing, weather information, business opportunity, ICT information are the major purpose of using ICT. Their study focused on the general ICT use purpose but the current study is focused on the use of IPDDS covering advice, disease control and weather information of the study conducted by Hassan *et al.* (2008).

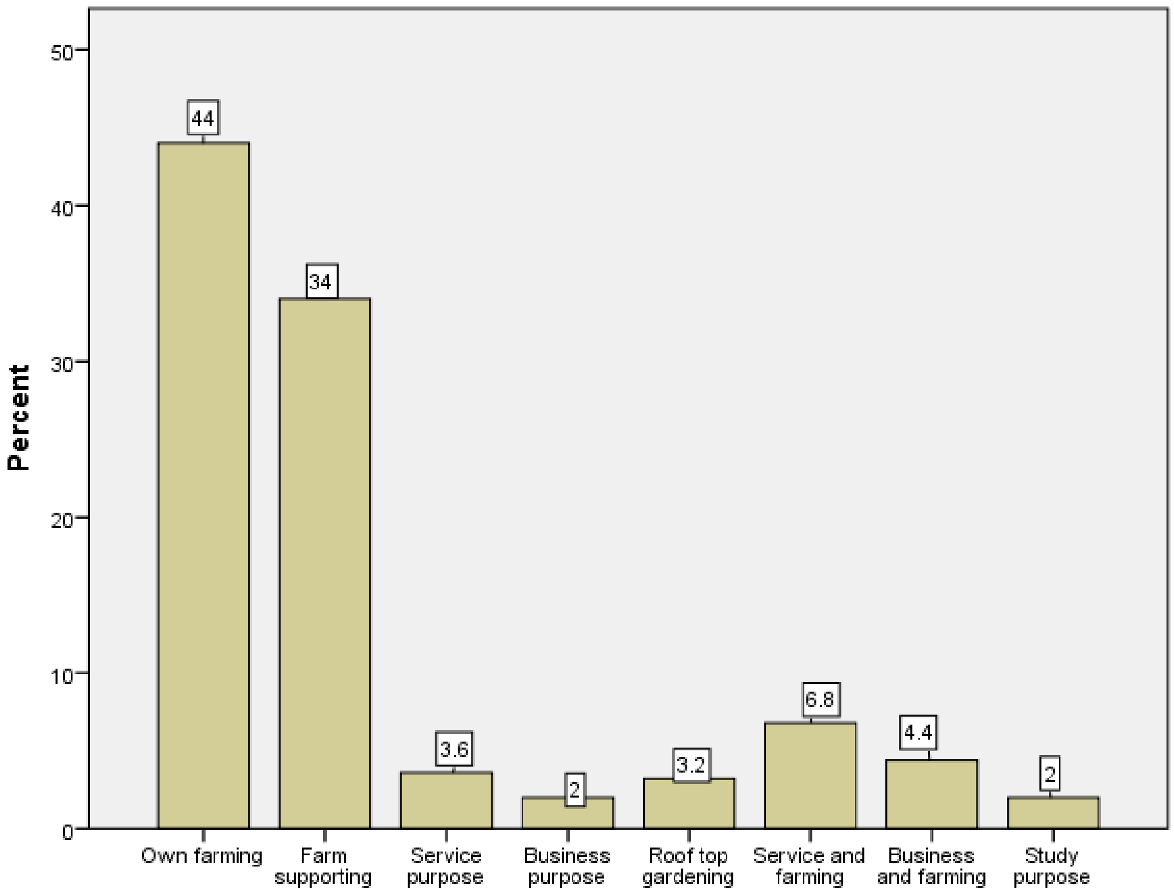

Fig. 4.1.1 Distribution of the users of IPDDS according to purpose of use

4.1.2 Profession of user

IPDDS is used for various proposes. Beside farmer, govt. service holders, private service holders, businessmen, and students were found to use IPDDS. The distribution of the users of IPDDS according to profession is shown in Figure 4.1.2. The figure showed that according to the profession of the user of IPDDS in percent farmer (36%) ranked first followed by private service holder (18.8%), businessman (17.2%), student (16.0%), and Govt. service holder

(12.0%). This is an indication of being IPDDS used by a wide range of professionals. Government Organization (GO) and Non-Government Organization (NGO) do not guarantee services to the all above mentioned professional people. The findings indicated that IPDDS was an alternative.

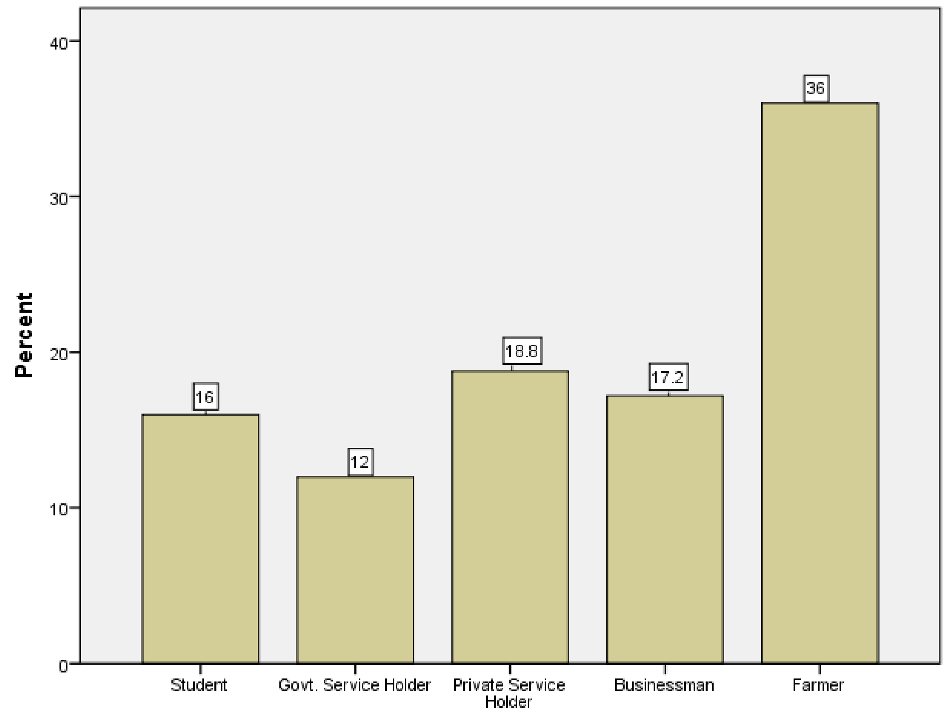

Fig. 4.1.2 Distribution of the users of IPDDS according to the profession

4.1.3 Gender of users

The distribution of the users of IPDDS according sex is shown in Figure 4.1.3.

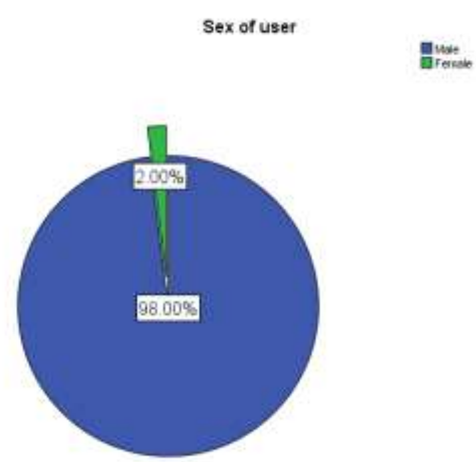

Fig. 4.1.3 Distribution of the users of IPDDS according to gender

The figure shows that 98.0% of the users were male and only 2.0% user were female. Campaigning should be done among the female regarding the use of IPDDS.

4.1.4 Geographical region of the user

Whole Bangladesh is divided into 14 agricultural regions for proper delivery of agricultural extension services to the farmer. Department of Agricultural Extension (DAE) provides agricultural extension services to the farmer all through 14 agricultural regions. Study sample covered all the regions. The distribution of the users of IPDDS according to the agricultural region is shown in Figure 4.1.4.

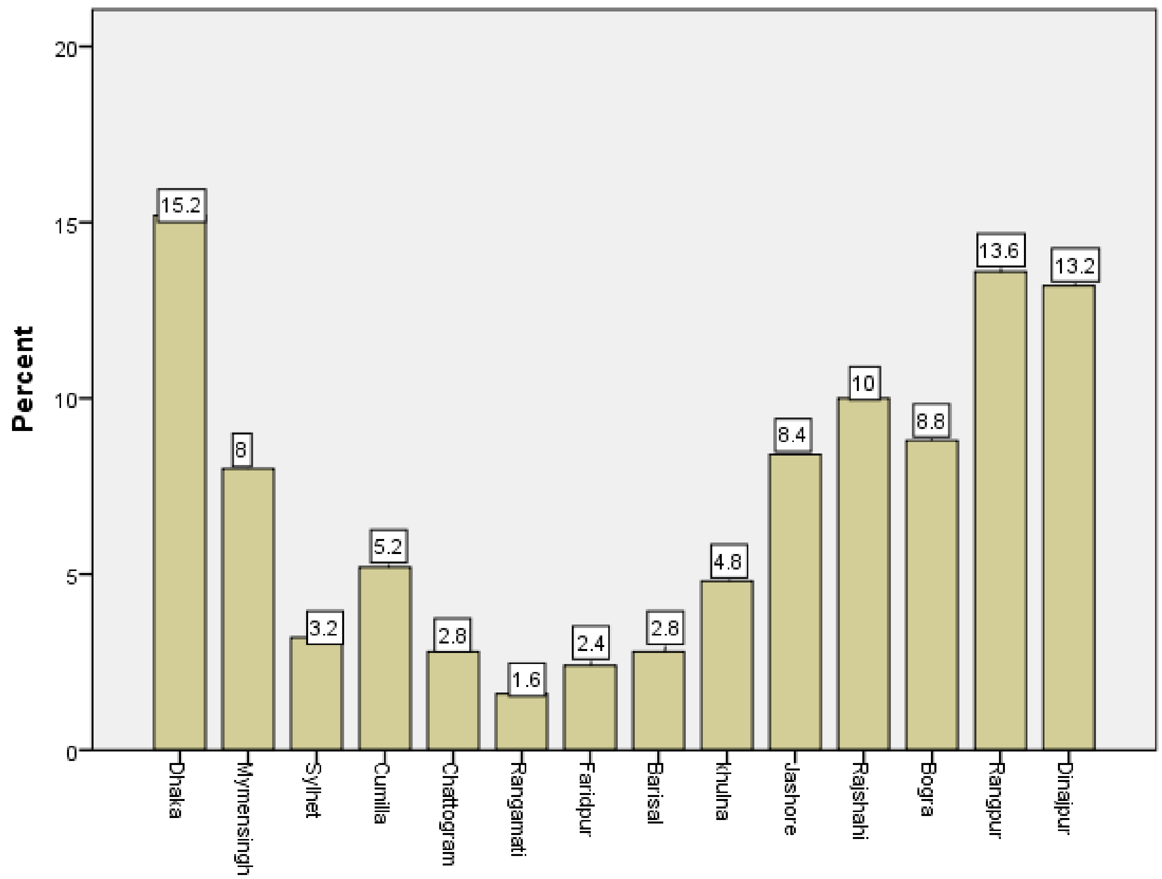

Fig. 4.1.4 Distribution of the users of IPDDS according to the agricultural regions

Figure 4.4 shows that according to the distribution of user in percent Dhaka region ranked first (15.2%) followed by Rangpur (13.6%), Dinajpur (13.2%) Rajshahi (10.0%), Bogra (8.8%), Jashore (8.4%), Mymensingh (6.0%), Cumilla (5.2%), Khulna (4.8%), Sylhet (3.2%), Chattogram (2.8%), Barisa (2.8%), Faridpur (2.4%) and Rangamati (1.6%). A cause behind

Dhaka region being first in ranking might be ICT advantages of users and socio-economic advancement. This also indicate that the respondents are quite fairly distributed.

4.2 Effectiveness of IPDDS

Effectiveness of IPDDS was the main focus of the study i.e. the dependent variable of the study. Effectiveness of IPDDS was measured based on the perception of the users on six (6) dimensions like system accuracy, user-friendliness, off-line usability, device responsiveness, content quality and user satisfaction. Under these six dimensions 22 items were selected to measure the effectiveness of IPDDS as described in Chapter 3 of this dissertation. Each of the 22 items was measured having a possible score ranging from 0-66 as shown in the question no. 15 of the interview schedule (Appendix I). Finally, effectiveness of IPDDS as perceived by users was measured by adding the scores obtained by them against all the 22 items. Measuring unit, possible range, observed range, mean, standard deviation (SD) and co-efficient of variance (CV) of the effectiveness of IPDDS as perceived by the users are shown in Table 4.1.

Table 4.1 Measuring unit, Possible and Observed range, Mean, Standard Deviation (SD) and Co-efficient of Variance (CV) of the effectiveness of IPDDS as perceived by the user respondents

Dependent Variable	Measuring unit	Possible range	Observed range	Mean	SD	CV %
Effectiveness of IPDDS as perceived by the users	Scores	0-66	14-65	38.84	9.221	23.74

Based on their effectiveness scores, the users were classified into three categories. The distribution of the users according to their perceived effectiveness of IPDDS is shown in Table 4.2. Data in the table showed that most of the users (77.90%) perceived that IPDDS was moderately effective while 19.50% user perceived as highly effective and 2.60% perceived as less effective in getting plant disease-related services.

Table 4.2 Distribution of the users according to their perceived effectiveness of IPDDS

User categories	Basis of categorization (Possible score)	Frequency	Percent
Low effectiveness	0 - 22	10	2.6
Moderate effectiveness	23 – 44	299	77.9
High effectiveness	>44	75	19.5
Total		**384**	**100**

This is an indication of being IPDDS useable in providing plant disease-related services in the field of agriculture. Findings also indicated that an overwhelming majority (80.5%) of the users perceived that IPDDS was low to moderate effective to detect plant diseases and getting plant diseases related services. Sultana *et al.* (2019) conducted study on Krisoker Janala -a Bangladeshi IPDDS and they reported that 64.2% of the respondents perceived Krisoker Janala as moderately effective while 24.5% and 11.3% of them perceived as less and highly effective respectively. Rupavatharam and Kennepohl (2018) studied the mobile application 'Plantix' an IPDDS that assists farmers in detecting damage on plants with the help of a smart phone image and reported that for over 100 classes the detection accuracy of plantix was over 90 %. They also reported that in some cases like early and late leaf spots of peanut an accuracy of over 95 % (15,000 images) was witnessed. Malek (2015b) also studied Krisoker Janala and reported that an overwhelming majority (94%) of the respondents had the opinion that the new intervention was most suitable for them.

A good number of studies were conducted on several models used for IPDDS and found different level of accuracy. Tetila *et al.* (2020), Wallelign *et al.* (2018), Sandino *et al.* (2018), Sibiya and Sumbwanyambe (2019) and Prakash *et al.* (2017) developed models for IPDDS and they claimed accuracy value of their models as 99.04%, 99.35%, 97.35%, 92.85%, and 90% respectively. Some of the models have been implemented and tested in real field situations by entrepreneurs or start-ups. R. U. Khan *et al.* (2021) reviewed the works on IPDDS done from 2016-2021 and showed that the accuracy of mostly used IPDDS models ranged from 78.00% to 99.70%. Although their study was on model performance; no real field study included, an idea about effectiveness of IPDDS found from their study and their findings support the findings of the current study.

4.2.1 Dimension and item wise comparative effectiveness of using IPDDS

To compare the dimension and item wise effectiveness of using IPDDS, Standardized Effect Index (SEI) was computed as described in Chapter 3 of this dissertation. The observed Standardized Effect Index (SEI) of the items ranged from 37.50% to 77.86 against the possible range of 0-100%. Rank order of the items were made based on the descending order of SEI among the dimensions and among all the items. Rank order was also prepared by the descending order of Average Standardized Effect Index (ASEI) of the dimensions as presented in Table 4.3.

4.2.1.1 Dimension wise comparison of the effectiveness of IPDDS

Based on ASEI 'user satisfaction' ranked first among the dimensions of effectiveness of IPDDS followed by 'system accuracy', 'user friendliness', 'content quality', 'offline usability' and 'device responsiveness' (Table 4.3).

Table 4.3 Effectiveness of IPDDS with Effectiveness Index (EI), Standardized Effectiveness Index (SEI) and rank order of each dimensions and items

Sl. no.	Items of effectiveness	Extent of effectiveness, number of users and rank order								Rank order		
		Highly effective (3)	Moderately effective (2)	Less effective (1)	Not at all effective (0)	Total	EI	SEI	Average SEI Among the dimension	Among the dimensions	Within the dimension	Among all the items
System accuracy												
1	Proper identification of plant disease	241	55	6	82	384	839	72.83			1	6
2	Smoothly working system	227	70	5	82	384	826	71.70	70.92	2	2	7
3	Negligible error in the system	189	106	7	82	384	786	68.23			3	8
User-friendliness												
4	Easy to use	142	150	8	84	384	734	63.72			1	10
5	Easy to remember how to use	127	63	69	125	384	576	50.00			5	15
6	Lower size of the software	144	89	27	124	384	637	55.30	56.23	3	4	13
7	Lower device hanging tendency	80	188	32	84	384	648	56.25			2	11
8	Comfort to use	75	195	29	85	384	644	55.90			3	12

Table 4.3 (Contd.)

Sl. no.	Items of effectiveness	Extent of effectiveness, number of users and rank order								Rank order		
		Highly effective (3)	Moderately effective (2)	Less effective (1)	Not at all effective (0)	Total	EI	SEI	Average SEI Among the dimension	Among the dimensions	Within the dimension	Among all the items
Device responsiveness												
9	Running in any smart device	41	130	86	127	384	469	40.71			19	19
10	Requirement of lower processor	16	146	92	130	384	432	37.50	39.32	6	21	22
11	Platform operability	44	115	96	129	384	458	39.76			20	20
Off-line usability												
12	Off-line running	105	121	34	124	384	591	51.30			1	14
13	Off-line installation	96	105	59	124	384	557	48.35	49.77	5	3	17
14	Off-line sharing	95	123	41	125	384	572	49.65			2	16
Content quality												
15	Usefulness of content	159	138	5	82	384	758	65.80			1	9
16	Updated content	37	125	93	129	384	454	39.41	50.55	4	3	21
17	Validity of content	35	203	24	122	384	535	46.44			2	18
User satisfaction												
18	Ease of the system	264	37	1	82	384	867	75.26			5	5
19	Delivery of the service	272	26	2	84	384	870	75.52			4	4
20	Service cost	272	28	2	82	384	874	75.87	76.37	1	3	3
21	On-time service	293	9	0	82	384	897	77.86			1	1
22	Time needed for getting service	287	15	0	82	384	891	77.34			2	2

User satisfaction: Based on ASEI 'user satisfaction' ranked first among the dimensions of effectiveness of IPDDS. Based on the descending order of SEI among five (5) items of user satisfaction, 'on-time service' ranked first followed by 'time needed for getting service', 'service cost', 'delivery of the service' and 'ease of the system'.

System accuracy: Based on the descending order of SEI among three (3) items of system accuracy, 'proper identification of plant disease' ranked first followed by 'smoothly working system', and 'negligible error in the system'.

User-friendliness: Based on the descending order of SEI among five (5) items of user friendliness, 'easy to use' ranked first followed by 'lower device hanging tendency', 'comfort to use', 'lower size of the software' and 'easy to remember how to use'.

Content quality: Based on the descending order of SEI among three (3) items of content quality, 'usefulness of content' ranked first followed by 'validity of content' and 'updates of content'.

Off-line usability: Based on the descending order of SEI among three (3) items of off-line usability, 'off-line running' ranked first followed by 'off-line sharing' and 'off-line installation'

Device responsiveness: Based on the descending order of SEI among three (3) items of device responsiveness, 'running in any smart device' ranked first followed by 'platform operability' and 'requirement of lower processor'.

Similar results have been reported by other researchers. Such as- student's satisfaction on an online software found to be dependent mostly on utility and flexibility; for these, usefulness, accuracy, ease of navigation, customized access, uptime, flexibility guidance, customized content were considered (Herlina *et al.*, 2013). Rongbutsri *et al.* (2017) measure the users' satisfaction on a learning mobile application based on functions and information of the application. Zhang *et al.* (2016) researched on 121 Chief Information Officer (CIO). By analyzing every of the 121 CIO's perspectives in the collaborative work sessions, they generated a total of 42 ways to assess Information Technology (IT) effectiveness. Of these, customer satisfaction tops the list, followed by project metrics, operational performance etc. Therefore, conclusion can be made that other researches also support the findings of the current study.

4.2.1.2 Item wise comparison of the effectiveness of IPDDS

Data in Table 4.3 revealed that according to descending order of Standardized Effectiveness Index (SEI), 'on-time service' ranked first among the items of effectiveness followed by 'time needed for getting service', 'service cost', 'delivery of the service', 'ease of the system', 'proper identification of plant disease', 'smoothly working system', 'negligible error in the system', 'usefulness of content', 'easy to use', 'lower device hanging tendency', 'comfort to use', 'lower size of the software', 'off-line running', 'easy to remember how to use', 'off-line sharing' 'off-line installation', 'validity of content', 'running in any smart device' platform operability', 'updated content' and 'requirement of lower processor'.

Findings from the study of Herlina *et al.* (2013) indicated that the best indicators that students mostly score for a good satisfaction were usefulness then ease of use, accuracy, ease of navigation respectively they reported that the worst indicators was customized access indicator. Effectiveness items of the current study are discussed below in descending order.

On-time service: Table 4.3 revealed that 'on-time service' ranked first (SEI = 77.86) among all items and within the dimension based on the descending order of EI and SEI of the items. It is very important for the respondents or users to save their crop from loss due to disease. Alam and Wagner (2013) assessed the impact of a digital procurement system via mobile phone and reported that service recipients get 30% more on-time service by using the system. Therefore, it can be said that on-time service is an important consideration for the effectiveness of IPDDS.

Time needed for getting service: It ranked second (SEI = 77.34) among all items based on the descending order of EI of the items. For assessing the effectiveness of IPDDS time needed for getting services is a very important item. Rupavatharam and Kennepohl (2018) studied the mobile application ‘Plantix’ an IPDDS that assists farmers in detecting damage on plants with the help of a smart phone image. They reported the system provide services to the user with in few second. The findings of their study support the findings of the current study.

Service cost: ‘Service cost’ ranked third among the items. De Silva and Ratnadiwakara (2008) reported a 33.0 percent reduction of costs in information search even without accounting for time saved. Therefore, it is justified to consider service cost paid by farmer for considering effectiveness of IPDDS.

Delivery of the service: ‘Delivery of the service’ ranked fourth among all the items based on the descending order of EI and SEI of the items. It is an important consideration for deciding the effectiveness of IPDDS. Sanga *et al.* (2016) studied the impact of mobile learning in Tanzania and reported that it bridging the gap in agricultural extension service delivery.

Ease of the system: ‘Ease of the system’ ranked 5th based on the effectiveness index of IPDDS. Kante *et al.* (2017) suggested that relative advantage, compatibility and simplicity and the delivered information quality were able to explain 77.9% of the variance in the use of ICTs to access and use agricultural input information.

Proper identification of plant disease: IPDDS used by farmer to identify plant disease properly. ‘Proper identification of plant disease’ ranked 6th based on the descending order of EI and SEI of the items.

Smoothly working system: It ranked 7th based on the descending order of EI and SEI of the items. It is important consideration for the farmers. If IPDDS work properly then user think it’s effectively positively.

Negligible error in the system: It ranked 8th based on the descending order of EI and SEI of the items. Farmers’ or users’ perceptions regarding the effectiveness of IPDDS is closely related to the system error. High error in the system affect farmer’s perceptions.

Usefulness of content: It ranked 9th based on the descending order of EI and SEI of the items. Wilson *et al.* (2021) described it as 'presentation' meaning the way of information are organized in a way that users can easily understand and 'understandability' meaning the extent to which information is clear, and unambiguous and easily interpretable to users' context.

Easy to use: It ranked 10th based on the descending order of EI and SEI of the items. The findings are supported by Kante *et al.* (2017). They suggested that relative advantage, compatibility and simplicity and the delivered information quality were able to explain 77.9% of the variance in the use of ICTs to access and use agricultural input information. That is compatibility or running the system in any smart device is a very important consideration in determining effectiveness of IPDDS.

Lower device hanging tendency: It ranked 11th based on the descending order of EI and SEI of the items.

Comfort to use: It ranked 12th based on the descending order of EI and SEI of the items. The findings are supported by Kante *et al.*(2017). They suggested that relative advantage, compatibility and simplicity and the delivered information quality were able to explain 77.9% of the variance in the use of ICTs to access and use agricultural input information. That is compatibility or running the system in any smart device is a very important consideration in determining effectiveness of IPDDS.

Lower size of the software: It ranked 13th based on the descending order of EI and SEI of the items.

Off-line running: It ranked 14th based on the descending order of EI and SEI of the items.

Easy to remember how to use: It ranked 15th based on the descending order of EI and SEI of the items.

Off-line sharing: It ranked 16th based on the descending order of EI and SEI of the items.

Off-line installation: It ranked 17th based on the descending order of EI and SEI of the items.

Validity of content: It ranked 18th based on the descending order of EI and SEI of the items. Wilson *et al.* (2021) identified accuracy, credibility, context-specific, completeness, relevancy and timeliness as the essential features of the information quality for an information system in agriculture which was substantiated through the preliminary analysis of user reviews on the agriculture mobile application

Running in any smart device: It ranked 19th based on the descending order of EI and SEI of the items. The findings are supported by Kante et al.(2017). They suggested that relative advantage, compatibility and simplicity and the delivered information quality were able to explain 77.9% of the variance in the use of ICTs to access and use agricultural input information. That is compatibility or running the system in any smart device is a very important consideration in determining effectiveness of IPDDS.

Platform operability: It ranked 20th based on the descending order of EI and SEI of the items.

Updated content: It ranked 21th based on the descending order of EI and SEI of the items. Wilson *et al.* (2021) reported context-specific, completeness and timeliness as the essential features of the information quality for an information system in agriculture which was substantiated through the preliminary analysis of user reviews on the agriculture mobile application.

Requirement of lower processor: It ranked 22th based on the descending order of EI and SEI of the items.

4.2.2 Findings from case study on Bangladeshi IPDDS 'Krishoker Janala'

During the period of conducting PhD research, the researcher conducted a case study titled 'Image-based plant disease detection system- an experience of Bangladesh' to find out the effectiveness of Bangladeshi IPDDS 'Krishoker Janala' as perceived by the user which is published in the Bangladesh Journal of Extension Education, Volume 32 in 2020. The study revealed that 84.62%, 11.54% and 3.85% respondent found Kriskoker Janala as highly effective, moderately effective and less effective respectively. The study also found that 92% of the respondents could solve their plants' problem using Krishoker Janala application by their own; did not need help from others. Study also revealed that it was an exceptional experience of Bangladesh in the field of image-based plant disease detection. The full article may be seen in Appendix VIII. From the field study of Karim *et al.* (2020) at Dakkhin Kharibari village in Tepa Kharibari union of Dimla Upazila under Nilphamari district of Bangladesh, it was known that 83.5% women farmers used Krishoker Janala for agricultural services. Their study also revealed that 'insect and disease control measures' was ranked first in the rank order of the agricultural activities according to the role of mobile phone. Krishoker Janala mostly deals with insect and disease control measures. Therefore, a conclusion can be drawn that there is evidence from other studies regarding the findings of the case study. The findings and experience of the case study helped in selecting the items and developing scale and questionnaire for the present study.

4.3 Characteristics of the IPDDS Users

The purpose of this section is to describe the 14 selected Characteristics of the sampled users of IPDDS as independent variables of the study. These Characteristics of the users are described in the following four (4) sub-sections of this Chapter. Procedure followed in measuring the characteristics have been described in Chapter 3. For describing the characteristics of the users, they were classified into suitable categories according to each of the characteristics. Category wise number and percentage distribution have been used to describe the characteristics.

4.3.1 Personal characteristics

Out of several personal characteristics of a user, four personal characteristics of the respondent users namely age, education, use of ICT and farming experience were selected for the present study. Salient features including measuring unit, possible and observed range, mean, Standard Deviation (SD) and Co-efficient of variance (CV) of the four selected personal characteristics of the users are presented in Table 4.4.

Table 4.4 Salient features including measuring unit, possible and observed range, Mean, Standard Deviation (SD) and Co-efficient of Variance (CV) of the four selected personal characteristics of the users

Characteristics	Measuring unit	Possible range	Observed range	Mean	SD	CV%
Age	Actual years	Unknown	14 - 63	28.23	7.804	27.64
Education	Schooling years	Unknown	4 - 17	14.10	2.621	18.59
Use of ICT	Score	0-8	2-8	6.01	1.475	24.54
Farming experience	Year	Unknown	0-40	6.13	6.104	99.58

4.3.1.1 Age

The observed age of the users ranged from 14 to 63 years, the mean being 28.23 with a standard deviation 7.804 and co-efficient of variation 27.64 (Table 4.4). Distribution of the users according to their age is shown in Table 4.5.

Table 4.5 Distribution of the users according to their age

Categories	Basis of categorization	Users	
		Number	Percent
Young aged	up to 35	333	86.7
Middle aged	>35-50	40	10.4
Old aged	>50	11	2.9
Total		384	100.0

Data contained in the Table 4.5 indicated that overwhelming majority (86.70%) of the users were young compared to 10.40 percent being middle aged and 2.90 percent old. Co- efficient of Variation (27.88%) of age of the respondents indicated that the sampled users were homogenous based on their age. The general notion found from the introduction of the newest technologies both within agriculture and outside of it is that older generations are the last to adopt them, while the younger generations typically embrace them more quickly (Dhraief, 2018). Aldosari *et al.* (2019) showed in their study that 34.4% and 33.3% respondents were belonged to the age group of 25–35 and 36–45 years respectively, only 10.9% respondents were below 25 years and 21.3% respondents were above 45 years. However, age of the respondent users was not significantly related (ρ = 0.014 at 0.05 level of probability) with their perceived effectiveness of the IPDDS. The findings imply that the age of the users were not an important factor for exerting the effectiveness of using IPDDS but the negative value of ‘ρ’ indicates that effectiveness of using IPDDS insignificantly degrease with increase of age.

4.3.1.2 Education

Education of the IPDDS users ranged from 4.0 to 17.0, the mean being 14.10 with the standard deviation of 2.621 and co-efficient of variation of 18.59%. The distribution of the users according to their education is shown in Table 4.6. Data presented in Table 4.6 indicated that the highest proportion (68.0%) of the users had tertiary level of education, compared to 20.6 percent higher secondary education level, 10.20 percent secondary level of education and 1.30 percent primary level of education. These finding indicated that cent percent (100%) of the respondents were literate with primary to tertiary level of education and it was higher level of education than the national average literacy rate of 72.8% (BBS, 2018a).

Table 4.6 Distribution of the users according to their education

Categories	Basis of categorization	Users	
		Number	Percent
Primary education	1 to 5	5	1.3
Secondary education	6 to 10	39	10.2
Higher secondary education	11 to 12	79	20.6
Tertiary education	above 12	261	68.0
Total		**384**	**100.0**

The reason behind this was that the sample users were of several group like farmers, business, service holders, students etc. Besides, IPDDS needs literacy to use it.

Co-efficient of variation of education of the sampled users (18.59%) indicated that the sampled users were homogenous based on their education. However, education of the sampled users was not significantly related (ρ = 0.015 at 0.05 level of probability) with their perceived effectiveness of using IPDDS. The findings imply that the education of the users were not an important factor for the effectiveness of IPDDS. The positive value of ‘ρ’ indicates that effectiveness of using IPDDS insignificantly increase with increase of level of education. This insignificance might be due to that all the users of IPDDS were educated and need very low technical knowledge to use IPDDS (need technical knowledge to use IPDDS ranked 8th among 10 obstacles of using IPDDS (Table 4.6).

4.3.1.3 Use of ICT

The observed range of extent of use of ICT of the sample users ranged from 2 to 8 with possible range 0-8, the mean being 6.01 with the standard deviation of 1.475 and co-efficient of variation 24.54% (Table 4.8). The sample users were classified into three categories based on the extent of use of ICT. Distribution of the users according to their extent of use of ICT is shown in Table 4.7.

Table 4.7 Distribution of the sample users according to use of ICT

User categories	Basis of categorization	Frequency	Percent
Low user	< (Mean - 1SD) i.e. < 4.538	21	5.5
Medium user	(Mean ± 1SD) i.e. 4.538 – 7.488	253	65.9
High user	> (Mean + 1 SD) i.e. >7.488	110	28.6
	Total	**384**	**100.0**

Data presented in Table 4.7 indicated that the about two-thirds (65.90%) of the respondents were medium user of ICT, compared to 28.60 percent high user of ICT and 12.80 percent low user. Findings again revealed that an overwhelming majority (94.5%) of the users were medium to high users of ICT.

Co-efficient variation (24.54%) of extent of use of ICT of the users indicated that the sampled users were homogenous based on their extent of use of ICT. However, extent of use of ICT of the sample users was significantly related (ρ = 0.168 at 0.01 level of probability) with their perceived effectiveness of using IPDDS. The findings imply that the extent of use of ICT of the users were an important factor for the effectiveness of using IPDDS.

4.3.1.4 Farming experience

The observed range of farming experience score of the users was 0 to 40, the mean being 6.13 with the standard deviation 6.104 and co-efficient of variation 99.58% (Table 4.8). The sample users were classified into three categories. Distribution of the users according to their farming experience in is shown in Table 4.8. Data presented in Table 4.8 indicated that an overwhelming majority (87.50%) of the users had medium farming experience, compared to 11.20 percent having long farming experience and 1.30 percent had short farming experience. Co-efficient of variation (99.58%) of experience in farming of the users indicated that the sampled users were heterogeneous based on their experience in farming. However, experience in farming of the sampled users was not significantly related (ρ = 0.039 at 0.05 level of probability) with their perceived effectiveness of using IPDDS. The findings imply that the farming experience of the users were not an important factor for the effectiveness of using IPDDS.

Table 4.8 Distribution of the users according to the farming experience of the user

Categories	Basis of categorization	Users	
		Number	Percent
Short farming experience	< (Mean - 1SD) i.e. < 0.026	5	1.3
Medium farming experience	(Mean ± 1SD) i.e. 0.026 – 12.234	336	87.5
Long farming experience	> (Mean + 1 SD) i.e. > 12.234	43	11.2
Total		**384**	**100.0**

4.3.2 Socio-economic characteristics

Salient features including measuring unit, possible and observed range, Mean, Standard Deviation (SD) and Co-efficient of variance (CV) of the four selected economic and social characteristics of the IPDDS users have been presented in Table 4.9. Six Socio-economic characteristics of the IPDDS users namely crop farm size, annual crop production income, time saved, cost saved, visit saved and individual extension contact were selected for the present study. Categories, number and percent distribution of these six selected economical characteristics have been discussed below in sub-sections.

Table 4.9 Salient features including measuring unit, possible and observed range, Mean, Standard Deviation (SD) and Co-efficient of variance (CV) of the six (6) selected Socio-economic characteristics of the users

Characteristics	Measuring unit	Possible range	Observed range	Mean	SD	CV%
Crop farm size	Decimal	Unknown	0-10000	264.03	585.95	221.92
Annual crop production income	'000' BDT	Unknown	0-3240	276.48	383.41	138.68
Time saved	Hours	Unknown	0-25	7.97	4.92	61.74
Cost saved	BDT	Unknown	0-1500	201.72	187.35	92.88
Visit saved	Frequency	Unknown	0-5	1.99	1.08	54.10
Individual extension contact	Scores	0-15	1-15	9.09	3.36	36.99

Data in Table 4.9 showed that standard deviation is higher than mean i.e. Co-efficient of Variation (CV) was more than 100% in some cases. Expert suggested using range or median to describe data when standard deviation is higher than mean to avoid misleading interpretation (Alrubaiee, personal communication).

4.3.2.1 Crop farm size

Crop farm size of the user respondents were found to range from 0-10000 decimal with an average of 264.03, standard deviation 585.95 and co-efficient of variation 221.92 percent (Table 4.9). Depending on the crop farm size, the users were classified into four categories such as marginal, small, medium and large crop farm size holder respondents as per guidelines of DAE (2007) and BBS (2006b) as shown in Table 4.10. Table 4.10 showed that among the user about 5.5% use IPDDS for roof top gardening purpose, 4.7% for service purpose, 2.6% for study purpose and 1.8% for business purpose and most of them have very low (0 or near about 0) crop farm size and annual crop production income which contributed to the incidence of being standard deviation higher than mean. But these data were not excluded due to importance of representation in the sample.

Table 4.10 Distribution of the users according to their crop farm size

Categories	Basis of categorization:	Users	
		Number	Percent
Marginal farm size	Up to 50	87	22.7
Small farm size	>50-247	176	45.8
Medium farm size	>247-741	97	25.3
Large farm size	>741	24	6.3
Total		**384**	**100**

Data furnished in Table 4.10 indicated that the highest proportion (45.8 percent) of the user respondents had small crop farm size while 25.3 percent and 15.9 percent medium and had marginal farm size respectively. Rest 6.3% of the respondents had large farm size. This was because of inclusion of diversified user of IPDDS in the study (co-efficient of variation 221.92 percent). However, crop farm size of the farming respondents had significant positive relationship ($\rho = 0.106$) with their perceived effectiveness of IPDDS.

4.3.2.2 Annual crop production income

The observed range of annual crop production income of the sampled users was 0 to 3240 thousand BDT, the mean being 276.48 with the standard deviation of 383.414 and co- efficient of variation 138.68% (Table 4.9). The sampled users were classified into three categories based on the range of annual crop production income. Distribution of the users according to their annual crop production income is shown in Table 4.11. Data presented in Table 4.11 indicated that the most of the user (65.60 percent) had medium income followed by 25.5% of the users had high income, 8.90 percent had low income from crop production. Co-efficient of variation (138.68%) of annual crop production income of the users indicated that the sample users were included from a wide range of diversity based on their annual crop production income.

Table 4.11 Distribution of the users according to their annual crop production income

Categories	Basis of categorization (Range)	Users	
		Number	Percent
Low income	0 - 10	34	8.9
Medium income	>10-300	252	65.6
High income	>300	98	25.5
Total		**384**	**100.0**

Among the user about 5.5% use IPDDS for roof top gardening purpose, 4.7% for service purpose, 2.6% for study purpose and 1.8% for business purpose (Table 4.1) and most of them have very low (0 or near about 0) farm size and annual crop production income which contributed to the incidence of being standard deviation higher than mean. But these data were not excluded due to importance of representation in the sample. However, annual crop production income of the sample users was positively associated ($\rho = 0.076^{NS}$, non-significant at 0.05 level) with their perceived effectiveness of using IPDDS. The findings imply that the annual crop production income of the users were not an important factor for the effectiveness of using IPDDS.

4.3.2.3 Time saved

Time saved by using IPDDS for detecting plant disease ranges from 0-25 hours with the mean of 7.97 and standard deviation of 4.92 and co-efficient of variation of 61.74 percent (Table 4.9). The user respondent of IPDDS were classified into three categories based on their time saved by using IPDDS for detecting plant disease. Distribution of the users according time they saved by using IPDDS is shown in Table 4.12. Data presented in Table 4.12 indicated that the most of the user (70.60 percent) saved medium time compared to 15.60% of the users saved low time, and rest 13.80 percent saved high time by using IPDDS. Findings again revealed that an overwhelming majority (84.4%) of the users saved medium to high time for getting plant disease-related services by using IPDDS. Malek (2015b) reported an average saving of time by 48% by using the IPDDS Krishoker Janala.

Table 4.12 Distribution of the users according to time they saved by using IPDDS

Categories	Basis of categorization	Users	
		Number	Percent
Low time saver	< (Mean - 1SD) <3.05	60	15.6
Medium time saver	(Mean - 1SD) - (Mean + 1SD) 3.05-12.89	271	70.6
High time saver	> (Mean - 1SD >12.89	53	13.8
Total		**384**	**100.0**

4.3.2.4 Cost saved

Cost saved by using IPDDS for detecting plant disease ranges from 0-1500 BDT with the mean of 201.72, standard deviation 187.35 and co-efficient of variation 92.88 percent (Table 4.9). The user respondents of IPDDS were classified into three categories based on their cost saved by using IPDDS for detecting plant disease. Distribution of the users according cost they saved by using IPDDS is shown in Table 4.13.

Table 4.13 Distribution of the users according to cost saved by user by using IPDDS

Categories	Basis of categorization	Users	
		Number	Percent
Low cost saver	< (Mean - 1SD) <14.36	43	11.2
Medium cost saver	(Mean - 1SD) - (Mean + 1SD) 14.36-389.07	291	75.8
High cost saver	> (Mean - 1SD >3.89.07	50	13.0
Total		**384**	**100.0**

Data presented in Table 4.13 indicated that the most of the users (75.80 percent) saved medium cost compared to 13.00% of the users saved high cost, 11.20 percent saved low cost by using IPDDS for detecting plant disease. Malek (2015b) reported an average saving of cost by 86% by using the IPDDS Krishoker Janala.

4.3.2.5 Visit saved

Visit saved by using IPDDS for detecting plant disease ranges from 0-5 with mean was of 1.99 standard deviation of 1.08 and co-efficient of variation of 54.10 percent (Table 4.9). The user respondent of IPDDS were classified into three categories based on their visit saved by using IPDDS for detecting plant disease. Distribution of the users according visit they saved by using IPDDS is shown in Table 4.14.

Table 4.14 Distribution of the users according to visit they saved by using IPDDS

Categories	Basis of categorization	Users	
		Number	Percent
Low visit saver	Up to 1	109	28.4
Medium visit saver	2-3	252	65.6
High visit saver	>3	23	6.0
Total		**384**	**100.0**

Data presented in Table 4.14 indicated that the most of the users (65.60 percent) saved medium visit compared to 28.40% of the users saved low visit, 6.0 percent saved high visit by using IPDDS for detecting plant disease. Malek (2015b) reported an average saving of visit of user by 66.66% by using the IPDDS 'Krishoker Janala' for getting plant pest related services.

4.3.2.5 Individual extension contact

The observed score of individual extension contact of the sample users ranged from 1 to 15 against the possible range of 0-15, the mean being 9.09 with the standard deviation of 3.36 and co-efficient of variation of 36.99% (Table 4.9). The sample users were classified into three categories based on individual extension contact. Distribution of the users according to their extension contact is shown in Table 4.15. Data presented in Table 4.15 indicated that the majority (69.3%) of the users had medium extension contact, followed by 16.7 percent having high extension contact and 14.10 percent had low individual extension contact.

Table 4.15 Distribution of the users according to their extension contact

Categories	Basis of categorization	Users	
		Number	Percent
Low extension contact	< (Mean - 1SD) i.e. < 5.72	54	14.1
Medium extension contact	(Mean ± 1SD) i.e. 5.72 – 12.45	266	69.3
High extension contact	> (Mean + 1 SD) i.e. > 12.45	64	16.7
Total		**384**	**100.0**

Findings again revealed that more than two-third (86.00%) of the users had medium to high individual extension contact.

Co-efficient of variation (36.99%) of extension contact of the users indicated that the users were homogenous based on their extension contact. However, individual extension contact of the users was positively related (ρ = 0.168 significant at 0.01 level) with their perceived effectiveness of using IPDDS.

4.3.3 Professional characteristics

Salient features including measuring unit, possible and observed range, Mean, Standard Deviation (SD) and Co-efficient of Variance (CV) of the four selected professional characteristics of the users have been presented in Table 4.16.

Table 4.16 Salient features including measuring unit, possible and observed range, Mean, Standard Deviation (SD) and Co-efficient of Variance (CV) of the four selected professional characteristics of the users

Characteristics	Measuring unit	Possible range	Observed range	Mean	SD	CV%
Knowledge on plant disease management	Scores	0 - 12	1-12	9.18	1.705	18.57
Use of IPDDS	Score	0-9	1-7	3.13	1.053	33.64
Benefit obtained by using IPDDS	Score	0-27	10-27	24.08	2.396	9.95
Obstacles faced in using IPDDS	Score	0 - 30	3-21	9.86	3.455	28.54

Four professional characteristics of the sample users namely knowledge on plant disease management, extent of use of IPDDS, obstacles faced in using IPDDS and benefit obtained by using IPDDS were selected for the present study. Categories, number and percent distribution of these four selected professional characteristics have been discussed in following subsections:

4.3.3.1 Knowledge on plant disease management

The observed score of knowledge on plant disease management of the users ranged from 1 to 12 against the possible range of 0-12, the mean being 9.18 with the standard deviation of 1.705 and co-efficient of variation of 18.57%. The users were classified into three categories based on their Knowledge on plant disease management. Distribution of the users according to their Knowledge on plant disease management is shown in Table 4.17. Data presented in Table 4.17 indicated that majority (66.4%) of the users had medium knowledge, compared to 21.6 percent had high knowledge and 12.0 percent had low knowledge on plant disease management. Findings again revealed that an overwhelming majority (82.0%) of the users had medium to high knowledge on plant disease management. Co-efficient of variation (18.57%) of knowledge on plant disease management of the users indicated that the users were homogenous based on their knowledge on plant disease management.

Table 4.17 Distribution of the users according to their Knowledge on plant disease Management

Categories	Basis of categorization	Users	
		Number	**Percent**
Low knowledge	< (Mean - 1SD) i.e. < 7.77	46	12.0
Medium knowledge	(Mean ± 1SD) i.e. 7.77 – 10.80	255	66.4
High knowledge	> (Mean + 1 SD) i.e. > 10.80	83	21.6
	Total	**384**	**100.0**

However, knowledge on plant disease management of the sample users were positively associated (ρ = 0.34, significant at 0.01 level) with their perceived effectiveness of using IPDDS. M. S. Ali (2008) also found a positive relationship between Knowledge on plant pest and disease management and effectiveness of IPDDS. Findings led to the conclusion that IPDDS has a role in increasing farmer's knowledge.

4.3.3.2 Use of IPDDS

Distribution of the users according to their extent of use of IPDDS is shown in Table 4.18.

Table 4.18 Distribution of the users according to their extent of use of IPDDS

Categories	Basis of categorization	Users	
		Number	**Percent**
Low use	< (Mean - 1SD) i.e. < 2.7	88	22.9
Medium use	(Mean ± 1SD) i.e. 2.7 – 4.18	244	63.5
High use	> (Mean + 1 SD) i.e. > 4.18	52	13.5
	Total	**384**	**100.0**

The observed score of extent of use of IPDDS of the users ranged from 1 to 7 against the possible range of 0 - 9 with the mean of 3.13 with the standard deviation of 1.053 and co-efficient of variation 33.64%. The users were classified into following three categories based on their extent of use of IPDDS. Data presented in Table 4.18 indicated that nearly two-third (63.5%) of the users had medium use, followed by 22.9 percent had low use and 13.5 percent had high extent of use of IPDDS. Findings again revealed that overwhelming majority (77.00%) of the users had medium to high use f IPDDS.

Co-efficient of Variation (33.64%) of extent of use of IPDDS of the users indicated that the users were homogenous based on their extent of use of IPDDS. However, extent of use of IPDDS of the sample users was positively associated (ρ = 0.205, significant at 0.01 level) with their perceived effectiveness of IPDDS. Attempt had been taken to determine the item wise use of IPDDS computing Use Index. The UI ranged from 6 to 1028 were possible range was unknown. Based on UI, rank order of IPDDS was made as shown in Table 4.19. Data in Table 4.19 revealed that based Standardized Use Index (SUI) Krishoker Janala ranked first followed by Plantix and Plant Doctor. No other IPDDS found to be used in Bangladesh. From the field study of Karim *et al.* (2020) at Dakkhin Kharibari village in Tepa Kharibari union of Dimla Upazila under Nilphamari district of Bangladesh, it was known that 83.5% of the women farmers used Krishoker Janala for agricultural services. Their study found no other IPDDS to be used by the women farmers in the study area.

Table 4.19 Use of IPDDS with rank order

Sl. No.	Name of IPDDS	Extent of Use						
		Regular use (3)	Occasional use (2)	Seldom use (1)	Not at all use (0)	UI	SUI	Rank order
1	Krishoker Janala	282	87	8	7	1028	87.24	1
2	Plantix	26	40	14	304	172	14.93	2
3	Plant Doctor	1	1	1	381	6	0.52	3

4.3.3.3 Benefits obtained by using IPDDS

Benefits obtained by using IPDDS score of the respondents was found to range from 10 to 27 against the possible range of 0 to 27 with mean, standard deviation and co-efficient of variation of 24.08, 2.40 and 9.95% respectively. On the basis of benefits obtained by using IPDDS, the respondents were classified into three categories as obtaining low benefit, medium benefit and high benefit from using IPDDS (Table 4.20).

Table 4.20 Distribution of the users according to Benefit obtained from using IPDDS

Categories	Basis of categorization (Mean and SD)	Users	
		Number	Percent
Low Benefit	<21.69	40	10.4
Medium Benefit	>(21.69 – 26.48)	284	74.0
High Benefit	>26.48	60	15.6
Total		**384**	**100.0**

Data presented in Table 4.20 indicated that the highest proportion (74 percent) of the respondents belonged to the group obtaining medium benefits by using IPDDS, while 10.4 and 15.6 percent belonged to the group obtaining low and high benefits by using IPDDS respectively. Thus, the majority (89.6 percent) of the farming respondents obtained medium to high benefits by using IPDDS. However, benefit obtained by using IPDDS of the respondents was positively related with their effectiveness of using IPDDS ($\rho = 0.266$, significant at 0.01 level). Item-wise benefits of using IPDDS of the users are described in table of section 5 of this chapter to compare among the benefit items.

4.3.3.4 Obstacles faced in using IPDDS

The observed obstacles faced in using IPDDS score of the users ranged from 3 to 21 against the possible ranged 0-30, the mean being 9.86 with the standard deviation of 3.46 and co-efficient of variation of 28.54% (Table 4.16). Based on their obstacles faced in using IPDDS, the users were classified into three categories. Distribution of the users according to obstacles faced in using IPDDS is shown in Table 4.21. Data contained in the Table 4.21 revealed that the highest proportion (74.00%) of the users had medium obstacle in using IPDDS compared to 15.6% and 10.40% having high and low obstacle in using IPDDS respectively. Since, 84.4% users face medium to high obstacles in using IPDDS. It needs to be improved and made more user friendly. Co-efficient of variation (28.54%) of obstacle faced in using IPDDS indicated that the users were homogenous based on their obstacles faced in using IPDDS. However, obstacles faced in using IPDDS had a negative relationship (ρ = -0.089, significant at 0.05 level) with their perceived effectiveness of using IPDDS. M. S. Ali (2008) also found problem faced in ecological agriculture had a negative relationship with adoption of ecological agricultural practices of the users.

Table 4.21 Distribution of the users according to obstacles faced in using IPDDS

Categories	Basis of categorization	Users	
		Number	**Percent**
Low obstacle	< (Mean - 1SD) i.e. < 21.68	40	10.40
Medium obstacle	(Mean ± 1SD) i.e. 21.68 – 26.48	284	74.00
High obstacle	> (Mean + 1 SD) i.e. > 26.28	60	15.60
	Total	**384**	**100.00**

It means that majority of the users were able to mitigate their obstacles faced in using IPDDS. It is assumed that the users having more capacity to mitigate their problems might have more capacity to determine their effectiveness of using IPDDS. Item-wise obstacles faced in using IPDDS of the users are described in the section 5 of this chapter to compare among the obstacle items.

4.4 Contribution and Effect of the Selected Characteristics of the Users to/on Their Perceived Effectiveness of IPDDS

The purpose of this section was to examine the contribution and effect of selected characteristics of the users to/on their perceived effectiveness of the IPDDS. Effectiveness of the IPDDS is a multivariate phenomenon involving interaction of many factors. Past studies on effectiveness of the IPDDS have brought to light a good number of characteristics of an individual that affect the perception behavior. For this purpose, fourteen (14) characteristics of the users were selected as the independent variables. First subsection of this section deals with the contribution of the selected characteristics of the respondents to their perceived effectiveness of IPDDS. The second subsection deals with the direct and indirect effects of the selected characteristics of the respondents to their perceived effectiveness of IPDDS.

4.4.1 Contribution of the selected characteristics of the users to their perceived effectiveness of IPDDS

The effectiveness of IPDDS (Y) was the dependent variable of this study. The procedure followed in measuring the dependent and independent variables has already been discussed in Chapter 3. Research and null hypotheses have been stated for testing the contribution/effect of the selected characteristics of the users to/on their perceived effectiveness of the IPDDS in Chapter 3. Spearman rank correlation test was initially run to test the relationships between each of the selected characteristics of the respondents and their perceived effectiveness of the IPDDS. The result of the correlation matrix containing inter-correlation among the variables is shown in Appendix VII. However, the results of correlation co-efficient of each of the selected characteristics of the respondents with their perceived effectiveness of the IPDDS are shown in Table 4.22. Correlation analysis showed that out of this fourteen (14) characteristics of the users, nine had significant relationship with their perceived effectiveness of IPDDS. Among the characteristics of the users, use of ICT (X_3), time saved (X_7), cost saved (X_8) and visit saved (X_9), individual extension contact (X_{10}), knowledge on plant disease management (X_{11}), use of IPDDS (X_{12}) and benefits obtained using IPDDS (X_{13}) had significant positive relationship and obstacles faced in using IPDDS (X_{14}) had significant negative relationship with their perceived effectiveness of IPDDS. On the other hand, age (X_1), education (X_2), farming experience (X_4) and annual crop production income (X_5) crop farm size (X_6) of the respondent had no significant relationship with their perceived effectiveness of IPDDS.

Table 4.22 Results of correlation co-efficient of each of the selected characteristics of the respondent users with their perceived effects of using IPDDS

Focus variable	Sample farming respondents characteristics	Value of Co-efficient of correlation (ρ) (Spearman's rho)
Effectiveness of the IPDDS (Y)	Age (X_1)	0.029
	Education (X_2)	-0.023
	Use of ICT (X_3)	0.134**
	Farming experience (X_4)	0.029
	Crop farm size (X_5)	0.064
	Annual crop production income (X_6)	0.088
	Time saved (X_7)	0.376**
	Cost saved (X_8)	0.192**
	Visit saved (X_9)	0.153**
	Individual extension contact (X_{10})	0.142**
	Knowledge on plant disease management (X_{11})	0.295**
	Use of IPDDS (X_{12})	0.202**
	Benefits obtained by using IPDDS (X_{13})	0.188**
	Obstacles faced in using IPDDS (X_{14})	-0.104*

*Significant at 0.05 Level and **Significant at 0.01 Level

Rashid and Islam (2016) reported that respondent's education, participation in training program, usages of e-Agriculture, attitude towards e-Agriculture and availability of e-Agriculture significantly influenced the problems faced by farmers in the use of e-agriculture. The study of Rashid and Islam (2016) and the current study had a reciprocal relationship between them. Because they had studied the problems faced by farmers in the use of e-agriculture and current research studied the effectiveness of IPDDS. The bridging point is that problems faced by farmers in the use of e-agriculture negatively affect the effectiveness of IPDDS.

The different characteristics of the respondents may interact together to make a combined contribution to the effectiveness of IPDDS. Keeping this fact in mind, linear multiple regression analysis was used to assess the contribution of the independent variables to the effectiveness of IPDDS. Full model multiple regression analyses were then run by involving all the independent variables with the effectiveness of IPDDS.

It was observed that the full model regression results were misleading. It might be due to the existence of multi-collinearity effect among the independent variables. It was evident from correlation matrix showing the interrelationships among the independent variables and existence of contradiction in the sign of correlation co-efficient and regression co- efficient. Draper and Smith (1981) suggested running stepwise multiple regression analysis to insert variables in turn until the regression equation is satisfactory. Therefore, in order to avoid the misleading results due to the problem of multi-collinearity and to determine the best explanatory variables, the method of step-wise multiple regression was employed by involving the all the independent variables. The results are presented in Table 4.23.

Table 4.23 Summary of stepwise multiple regression analysis showing the contribution of 14 independent variables to the effectiveness of IPDDS

Variables entered	Standardized partial 'b' coefficient	Value of 't' (with probability level)	Adjusted R^2	Increase in R^2	Variation explained in percent
Time saved (X_7)	0.417	9.84 (0.000)	0.233	0.233	23.3
Knowledge on plant disease management (X_{11})	0.208	4.78 (0.000)	0.297	0.064	6.4
Benefits obtained by using IPDDS (X_{13})	0.208	4.86 (0.000)	0.329	0.032	3.2
Obstacles faced in using IPDDS (X_{14})	-0.107	-2.49 (0.013)	0.339	0.010	1.0
Use of ICT (X_3)	0.088	2.08 (0.038)	0.345	0.006	0.6
	Total			**0.345**	**34.5**

Multiple R = 0.594

R-square = 0.353

Adjusted R^2 = 0.345

F-ratio = 41.264 at 0.000 level of significance

The remaining variables i.e. age (X_1), education (X_2), annual crop production income (X_5), farming experience (X_4), crop farm size (X_6), individual extension contact (X_{10}), cost saved (X_8), and visit saved (X_9) were not entered as those variables were not significant in correlation test.

Multiple R, R^2 and adjusted R^2 in the step-wise multiple regression analysis were 0.594, 0.353 and 0.345 respectively, and the corresponding F-ratio of 41.264 was significant at 0.000 level. The regression equation so obtained is presented below:

$$Y = 2.433 + 0.417(X_7) + 0.208(X_{11}) + 0.208(X_{13}) - 0.107(X_{14}) + 0.088(X_3)$$

Adjusted R^2 = 0.345
F-ratio=41.264
Constant = 2.433

The findings indicated that the whole model of five (5) variables explained 34.5 percent of the total variation the effectiveness of IPDDS while the remaining percentage was attributed to error term. But since the standardized regression coefficients (Beta weight) of four (5) variables formed the equation and were significant, it might be assumed that whatever contribution was there, it was due to these five (5) variables.

Analysis of data presented in Tables 4.23 and regression equations indicated that in different combinations, standardized partial regression co-efficient of five independent variables were significant out of fourteen (14) independent variables with the effectiveness of IPDDS. It was observed that regression co-efficient between some of these five independent variables and effectiveness of IPDDS as dependent variable had different probability levels (0.000 to 0.038) in different model. It could logically happen due to the existence of interrelationship among the different independent variables. Similar observations were experienced by different researchers like Rashid and Islam (2016) and M. S. Ali (2008). Attempts had been taken to run step-wise multiple regression by involving the significant variables after correlation test. Same result was produced. Therefore, the result was treated as the final model which may otherwise be considered as the best explanatory model.

Based on the stepwise regression analysis, contributions of significant five (5) independent variables to the effectiveness of IPDDS as the dependent variable are presented below in order of importance.

Time saved (X_7): The co-efficient of correlation showed significant positive relationship between the time saved (X_7) by the users and the effectiveness of IPDDS (Appendix VII). Step-wise multiple regression analysis indicated that the time saved (X_7) by the users in detecting plant disease had strong significant and positive contribution to their perceived effectiveness of IPDDS. Time saved (X_7) by the users in detecting plant disease was found to be the most important positive contributor to the effectiveness of IPDDS. Time saved (X_7) by the users in detecting plant disease increases their positive perception on the effectiveness of IPDDS. From the stepwise multiple regressions, it was concluded that time saved (X_7) by the users in detecting plant disease had first highest positive contribution to their perceived effectiveness of IPDDS. This implies that with the increase of time saved (X_7) by the users in detecting plant disease will increase their positive perception on the effectiveness of IPDDS.

Knowledge on plant disease management (X_{11}): Spearman rank correlation test showed significant positive relationship between the knowledge on plant disease management (X_{11}) and the effectiveness of IPDDS (Appendix VII). Step-wise multiple regression analysis indicated that knowledge on plant disease management (X_{11}) had strong significant and positive contribution to their perceived effectiveness of IPDDS. Knowledge on plant disease management (X_{11}) increases their positive perception on the effectiveness of IPDDS. From the stepwise multiple regressions, it was concluded that knowledge on plant disease management (X_{11}) had positive contribution to their perceived effectiveness of IPDDS. This implies that with the increase of knowledge on plant disease management (X_{11}) will increase their positive perception on the effectiveness of IPDDS.

Benefits obtained by using IPDDS (X_{13}): Spearman rank correlation test showed significant positive relationship between the benefits obtained by using IPDDS (X_{13}) and the effectiveness of IPDDS (Appendix VII). Step-wise multiple regression analysis indicated that benefits obtained by using IPDDS (X_{13}) had strong significant and positive contribution to their perceived effectiveness of IPDDS. Benefits obtained by using IPDDS (X_{13}) increases their positive perception on the effectiveness of IPDDS. From the stepwise multiple regressions, it was concluded that benefits obtained by using IPDDS (X_{13}) had positive contribution to their perceived effectiveness of IPDDS. This implies that with the increase of benefits obtained by using IPDDS (X_{13}) will increase their positive perception on the effectiveness of IPDDS.

Obstacles faced in using IPDDS (X_{14}): Pearson product moment correlation co-efficient revealed that obstacles faced in using IPDDS (X_{14}) had significant but negative correlation with their perceived effectiveness of IPDDS (Appendix VII).

Step-wise multiple regression analysis indicated that obstacles faced in using IPDDS (X_{14}) was an important contributor and had significant but negative contribution to their perceived effectiveness of IPDDS.

It is quite logical that the users who faced more obstacles in using IPDDS (X_{14}) were not satisfied on the effectiveness of IPDDS. This might be the reason for obstacles faced in using IPDDS (X_{14}) having the negative contribution to their perceived effectiveness of IPDDS.

Use of ICT (X_3): Spearman rank correlation test showed a significant positive relationship between the use of ICT (X_3) and the effectiveness of IPDDS (Appendix VII). Step-wise multiple regression analysis indicated that the use of ICT (X_3) had a strong significant and positive contribution to their perceived effectiveness of IPDDS. The use of ICT (X_3) increases their positive perception of the effectiveness of IPDDS. From the stepwise multiple regressions, it was concluded that the use of ICT (X_3) had a positive contribution to the perceived effectiveness of IPDDS. This implies that the increase of use of ICT (X_3) will increase their positive perception of the effectiveness of IPDDS.

4.4.2 Direct and indirect effects of the selected characteristics of the users on their perceived effectiveness of using IPDDS

In the present study Spearman's rank correlation test, full model linear multiple regression and stepwise multiple regression were conducted. It is not possible to find out the direct effects and indirect effects separately by these tests. But path analysis, can make it possible to get direct effects and indirect effects separately. According to Dewey and Lu (1959) Path coefficient is simply a standardized partial regression coefficient and as such measures the direct influence of one variable upon another and permits the separation of the correlation coefficient into components of direct and indirect effects (Dewey and Lu, 1959, p. 5015-518). This allows the reflection of direct effect of an independent variable and its indirect effect through other variables on the dependent variable as used by Walle *et al.* (2018).

Direct effect of an independent variable on the dependent variable is the standardized beta co-efficient (value of 'b' of regression analysis) of the respective independent variable. Whereas indirect effect of an independent variable through a channeled variable is measured by the following formula:

$$\mathbf{e = b \times \rho}$$

Where,

e = Indirect effect of an independent variable

b = Direct effect of the variable through which indirect effect is channeled

ρ = Spearman correlation co-efficient between respective independent variable and variable through which indirect effect is channeled.

Path coefficient analysis was employed in order to obtain a clear understanding of the direct and indirect effects of selected independent variables. Path analysis was done involving the significant variables of step-wise multiple regression analysis. Path coefficients showing the direct and indirect effects of significant 5 independent variables of step-wise multiple regression analysis on the users' perception on the effectiveness of IPDDS have been presented in Table 4.24.

Table 4.24 Path coefficients showing the direct and indirect effects of five (5) significant independent variables of stepwise multiple regression analysis on the effectiveness of IPDDS

Independent variables	Variables through which indirect effects are channeled	Standardized partial 'b' coefficient of channeled variable	Value of Co-efficient of correlation (r) between selected independent variable and channeled	Indirect effects	Total indirect effect	Direct effect
Time saved (X_7)	Knowledge on plant disease management (X_{11})	0.208	0.176	0.037	0.06	0.417
	Benefits obtained by using IPDDS (X_{13})	0.208	0.124	0.026		
	Obstacles faced in using IPDDS (X_{14})	-0.107	0.025	-0.003		
	Use of ICT (X_3)	0.088	0.037	0.003		
Knowledge on plant disease management (X_{11})	Time saved (X_7)	0.417	0.176	0.073	0.11	0.208
	Benefits obtained by using IPDDS (X_{13})	0.208	0.035	0.007		
	Obstacles faced in using IPDDS (X_{14})	-0.107	-0.158	0.017		
	Use of ICT (X_3)	0.088	0.186	0.016		
Benefits obtained by using IPDDS (X_{13})	Time saved (X_7)	0.417	0.124	0.052	0.03	0.208
	Knowledge on plant disease management (X_{11})	0.208	0.035	0.007		
	Obstacles faced in using IPDDS (X_{14})	-0.107	0.299	-0.032		
	Use of ICT (X_3)	0.088	-0.006	-0.001		
Obstacles faced in using IPDDS (X_{14})	Time saved (X_7)	0.417	0.025	0.010	0.03	-0.107
	Knowledge on plant disease management (X_{11})	0.208	-0.158	-0.033		
	Benefits obtained by using IPDDS (X_{13})	0.208	0.299	0.062		
	Use of ICT use (X_3)	0.088	-0.083	-0.007		

Table 4.24 Path coefficients showing the direct and indirect effects (Contd.)

Use of ICT (X_3)	Time saved (X_7)	0.417	0.037	0.015	0.06	0.088
	Knowledge on plant disease management (X_{11})	0.208	0.186	0.039		
	Benefits obtained by using IPDDS (X_{13})	0.208	0.006	0.001		
	Obstacles faced in using IPDDS (X_{14})	-0.107	-0.083	0.009		

Analysis of data furnished in Table 4.23 indicated that among the independent variables, time saved (X_7) by the user had the highest direct effect (0.417) in the positive direction effect on their perception on the effectiveness of using IPDDS. Knowledge on plant disease management (X_7), benefits of using IPDDS (X_{13}), and use of ICT (X_3) had appreciable positive direct effect in the positive direction on users' perception on the effectiveness of using IPDDS and their direct effect were 0.208, 0.208 and 0.088 respectively. Use of ICT (X_3) of the users had the lowest direct positive effect (0.088) to their perception on the effectiveness of using IPDDS. Obstacles faced in using IPDDS (X_{14}) had direct negative effect (-0.107) on users' perception on the effectiveness of using IPDDS.

Here, it may be mentioned that without path co-efficient analysis it is not possible to know the indirect effects of an independent variable through other variables on the dependent variable. Therefore, this study felt need to calculate the indirect effects which have been obtained from path co-efficient analysis (Table 4.24).

Results of path analysis, the direct and indirect effects and their directions are shown in the diagram in Figure 4.5.

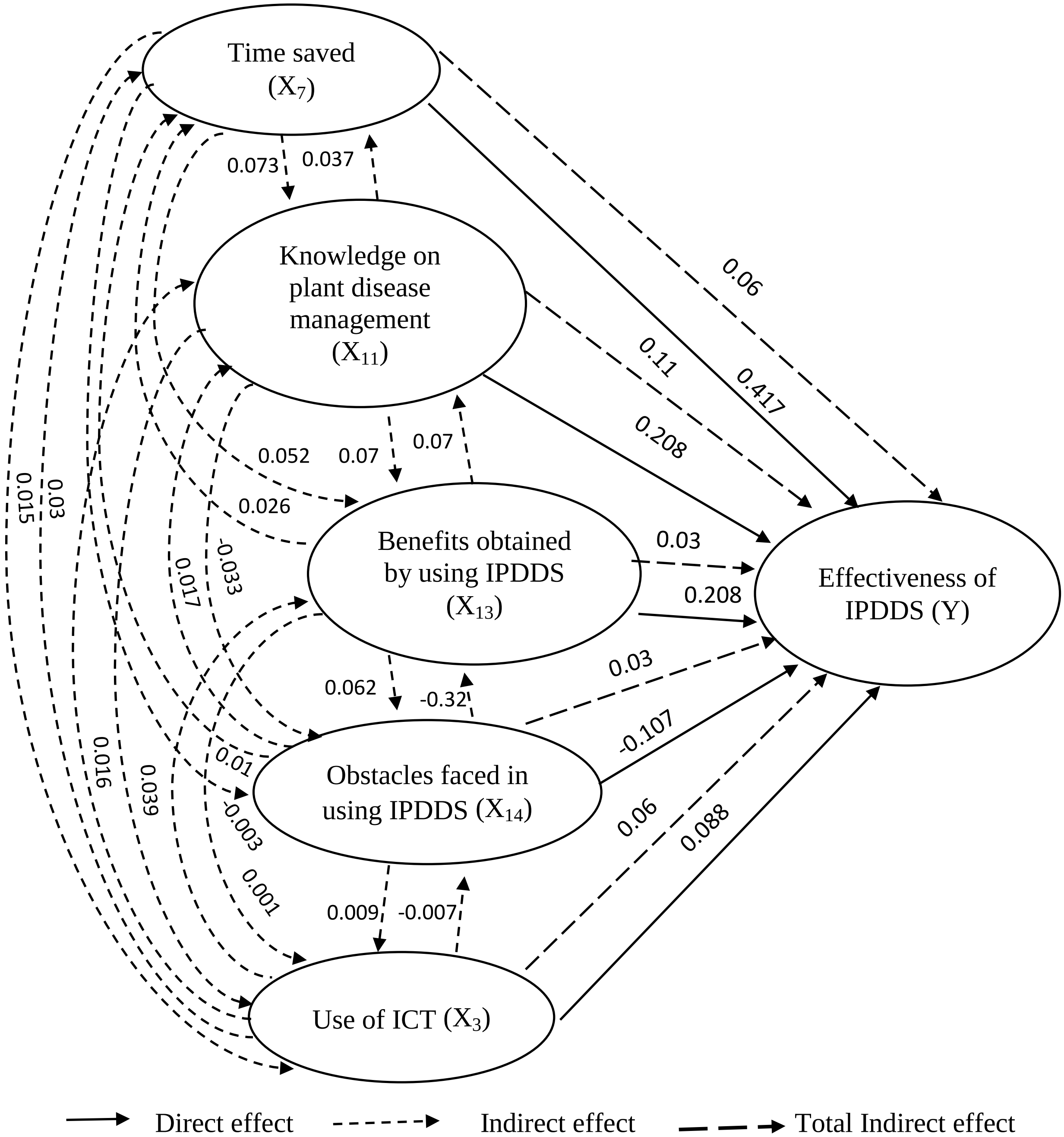

Fig. 4.5 Diagram showing the direct and indirect effect of variables on the effectiveness of IPDDS

On the basis of path analysis, the independent variables having indirect effects on the effectiveness of using IPDDS have been presented below in descending order.

Knowledge on plant disease management (X_{11}): Path analysis (Table 4.24) showed that knowledge on plant disease management (X_{11}) of the sample users had the highest total indirect effect (0.11) and a positive direct effect of 0.208 on their perceived effectiveness of IPDDS. The indirect effect was mostly channeled positively through time saved (X_7) by the user. The indirect effect of knowledge on plant disease management (X_{11}) was somewhat positively channeled through the benefits of using IPDDS (X_{13}), use of ICT (X_3) and the obstacles faced in using IPDDS (X_{14}). It may be inferred that other variables remaining constant, knowledge on plant disease management (X_{11}) had an influence on the effectiveness of using IPDDS and was a determinant of the effectiveness of using IPDDS.

Time saved (X_7): Path analysis (Table 4.24) showed that time saved (X_7) of the sample users had the 2nd highest total indirect effect (0.060) and a positive direct effect of 0.417 on their perceived effectiveness of IPDDS. The indirect effect was mostly channeled positively through knowledge on plant disease management (X_{11}). The indirect effect of time saved (X_7) was somewhat positively channeled through the benefits of using IPDDS (X_{13}) and the use of ICT (X_3). The indirect effect of time saved (X_7) was somewhat negatively channeled through the obstacles faced in using IPDDS (X_{14}). It may be inferred that other variables remaining constant, time saved (X_7) of the sample users had an influence on the effectiveness of using IPDDS and was a determinant of the effectiveness of using IPDDS.

Use of ICT (X_3): Path analysis (Table 4.24) showed that use of ICT (X_3) of the sample users also had the 2nd highest total indirect effect (0.060) and a positive direct effect of 0.088 on their perceived effectiveness of IPDDS. The indirect effect was mostly channeled positively through knowledge on plant disease management (X_{11}). The indirect effect of use of ICT (X_3) was somewhat positively channeled through the benefits of using IPDDS (X_{14}), obstacles faced in using IPDDS (X_{13}) and use of ICT (X_3). It may be inferred that other variables remaining constant, the use of ICT (X_3) of the sample users had an influence on the effectiveness of using IPDDS and was a determinant of the effectiveness of using IPDDS.

Benefits of using IPDDS (X_{14}): Path analysis (Table 4.24) showed that benefits of using IPDDS (X_{14}) of the sample users had the 3rd highest total indirect effect (0.030) and a positive direct effect of 0.208 on their perceived effectiveness of IPDDS. The indirect effect was mostly channeled positively through time saved (X_7). The indirect effect of benefits obtained by using IPDDS (X_{13}) was somewhat positively channeled through knowledge on plant disease management (X_{11}). The indirect effect of benefits of using IPDDS (X_{13}) of the sample users was somewhat negatively channeled through obstacles faced in using IPDDS (X_{14}) and the use of ICT (X_3). There was negligible indirect effect of the benefits of using IPDDS (X_{13}) of the sample users of the sample users on their perceived effectiveness of using IPDDS. It may be inferred that other variables remaining constant, Benefits of using IPDDS (X_{13}) of the sample users had an influence on the effectiveness of using IPDDS and was a determinant of the effectiveness of using IPDDS.

Obstacles faced in using IPDDS (X_{14}): Path analysis (Table 4.24) showed that the obstacles faced in using IPDDS (X_{14}) of the sample users had the 3rd highest total indirect effect (0.030) and a negative direct effect of -0.107 on their perceived effectiveness of IPDDS. The indirect effect was mostly channeled positively through the benefits of using IPDDS (X_{13}). The indirect effect of obstacles faced in using IPDDS (X_{14}) was somewhat positively channeled through time saved (X_7) and negatively channeled through knowledge on plant disease management (X_{11}) and use of ICT (X_3). There was very negligible indirect effect of obstacles faced in using IPDDS (X_{14}) of the sample users on their perceived effectiveness of using IPDDS. It may be inferred that other variables remaining constant, obstacles faced in using IPDDS (X_{14}) of the sample users had an influence on the effectiveness of using IPDDS and was a determinant of the effectiveness of using IPDDS.

4.5 Comparative Benefits Obtained and Obstacles Faced in Using IPDDS

4.5.1 Benefits obtained by using IPDDS

To compare the item wise benefits obtained by using IPDDS, Benefit Index (BI) and Standard Benefit Index (SBI) were computed as described in Chapter 3 of this dissertation. The observed SBI of the items of benefits obtained by using IPDDS ranged from 59.72 to 98.87

against the possible range of 0-100. The observed BI of the items ranged from 688 to 1139 against the possible range of 0-1152. BI and SBI of each items with rank order of SBI is presented in Table 4.25.

Table 4.25 Standard Benefit Index (SBI) of using IPDDS of each items with rank order

Sl. no.	Items of Benefits	Extent of Benefit and users				BI	SBI	Rank order
		High Benefit (3)	Moderate Benefit (2)	Low Benefit (1)	Not at all Benefit (0)			
1	Reduce time for detecting disease	373	9	2	0	1139	98.87	1
2	Reduce disease detecting cost	344	37	3	0	1109	96.27	5
3	Increase production	233	143	8	0	993	86.20	7
4	Increase service accessibility	351	30	3	0	1116	96.88	2
5	Increase service quality	350	31	3	0	1115	96.79	4
6	Reduce pesticide use	86	150	130	18	688	59.72	9
7	Increase net income	165	199	20	0	913	79.25	8
8	Increase respondents' knowledge	349	33	2	0	1115	96.79	4
9	Increase quality of produces	287	90	7	0	1048	90.97	6

Data in Table 4.25 revealed that according to descending order of Standard Benefit Index (SBI), 'reduce time for detecting disease' ranked first followed by 'increase service accessibility', 'increase service quality', 'increase respondents' knowledge', 'reduce disease detecting cost', 'increase quality of produces', 'increase production', 'increase net income' and 'reduce pesticide use'. Benefit items are discussed below in ascending order.

Reduce time for detecting disease ranked first (BI=1139) based on the descending order of BI of the items. For user or any other user time needed for getting services is a very important item. Rupavatharam and Kennepohl (2018) reported that 'Plantix' provided services to the user with in few second. The findings of their study support the findings of the current study. Based on the descending order of Standard Benefit Index (SBI), 'reduce time for detecting disease' ranked first followed by 'increase service accessibility' etc. This might be due to the fact that farmers and other users are very conscious about the time needed for getting a service. Since users are getting the service real-time on the spot by using IPDDS, they are considering time reduction as the most important item of benefit obtained by using IPDDS. Among the benefit items 'increase service accessibility' ranked second. It was observed in case study and user's response that users are getting service as and when necessary. They manage to keep themselves ready for solving plant disease related problems. Whenever a disease appear they just open the application and have the solution. Previously, they had to spent huge time for visiting agricultural office or extension service provider. Other items of benefits found to be very relevant to the farmer's actual needs in the preproduction, production and post production period. Items like 'increase service quality', 'reduce disease detecting cost', 'increase quality of produces', 'increase production', and 'increase net income' are directly related to the financial benefits. 'Increase respondents' knowledge', and 'reduce pesticide use' are seriously important items for environment and public health issue. By using IPDDS a user can directly reduce the use of pesticides and the increased knowledge of the user can make user conscious about public health and environment. Distribution of the users according to benefit obtained from using IPDDS is presented in Table 4.20 of this chapter.

4.5.2 Obstacles faced by the farmer in using IPDDS

To compare the item-wise obstacles faced by farmers in using IPDDS, Obstacle Index (OI) and Standard Obstacle Index (SOI) was computed for each item by using the formula discussed chapter 3.

The observed OI of the items ranged from 31 to 841 against the possible range of 0-1152 and SOI of the items ranged from 2.69 to 73.00 against the possible range of 0-100. OI, SOI, and rank order of each item are presented in Table 4.26.

Table 4.26 Standardized Obstacle Index (SOI) of using IPDDS of each item with rank order

Sl. no.	Items of obstacle	The extent of obstacle faced user farmer								
									Rank order	
		Severe obstacle (3)	Moderate obstacle (2)	Less obstacle (1)	No obstacle (0)	Total	OI	SOI	Among the dimension	Among all the items
A. Socio-economic problems										
1	Illiteracy	150	162	67	5	384	841	73.00	1	1
2	Unavailability of smart phone	83	90	179	32		608	52.78	2	3
B. Technical problems										
3	Lack of sufficient internet speed	17	44	92	230	384	231	20.05	3	6
4	Need technical knowledge to use IPDDS	5	14	75	290	384	118	10.24	4	8
5	Inadequate extension service to support the use of IPDDS	4	80	124	176	384	296	25.69	2	5
6	The inability of disease detection at an early stage	61	260	54	9	384	757	65.71	1	2
7	Presence of multiple diseases in the same plant	2	8	70	304	384	92	7.99	5	9
8	Presence of the background of the image	4	2	15	363	384	31	2.69	6	10
C. Psychological problems										
9	Apathy to use IPDDS	1	18	98	267	384	137	11.89	2	7
10	ICT phobia	38	141	189	16	384	585	50.78	1	4

Thus the range of SOI of the items could be 0-100, where ‘0’ indicated no SOI and ‘100’ indicated the highest SOI. Based on the descending order of SOI rank order of the item (among the dimension and all the items) were made to understand the importance of the items.

Data in Table 4.26 revealed that according to descending order of Standardized Obstacle Index (SOI) ‘illiteracy’, ranked first among the items of obstacles followed by ‘inability of disease detection at an early stage’, ‘unavailability of the smart phone’, ‘ICT phobia’, ‘inadequate extension service to support the use of IPDDS’, ‘lack of sufficient internet speed’, apathy to use IPDDS’, ‘need technical knowledge to use IPDDS’, ‘presence of multiple diseases in same plant’ and ‘presence of background of the image’. Obstacle items are discussed below in ascending order. The significance of the findings presented in table 3.1 is that it indicates the important socio-economic, technical, and psychological obstacles faced by the farmer in using IPDDS which are important in planning, policy formulation, and framing strategy for ICT intervention for providing agricultural advisory services to the farmer. The rank order of the item indicates the importance of the obstacles faced by the farmer in using IPDDS. Thar *et al.* (2021) in their study explored the agricultural mobile apps available in Myanmar, analyzed factors affecting their use and assessed the potential for farm-based decision support and reported lack of access to smartphone and/or internet (63%) and lack of digital knowledge (20%) as the main constraints to adopt agricultural apps. Rashid and Islam (2016) studied the problems faced by farmer in using e-agriculture and reported that among the problems, lack of farmer’s knowledge on e-agriculture ranked first followed by inadequate government digital service centers and facilities, lower internet speed, quality of information, inadequate ICT experts, lack of awareness towards benefits of ICT in agriculture, user-friendliness of the technology, expensive to use, apathy towards new technology, lack of training, inadequate number of e-agriculture related programs in electronic media, miserable electricity connections and lack of relevant customized content respectively. Rashid and Islam (2016) studied e-agriculture as a whole but the current study was on the IPDDS an important part of e-agriculture. Common obstacles found from both studies are: ‘inadequate extension service to support the use’, ‘lack of sufficient internet speed’, apathy to use’, and ‘need technical knowledge to use’.

Khalak *et al.* (2018) reported poor level of education, lack of knowledge on the availability of ICT facilities, lack of operational knowledge of computer, social and religious restriction, limited number of ICT center, high cost of internet service, lack of personal interest, low bandwidth speed of internet, lack of ICT software, electricity problem, lack of training facilities as problems faced by them farmers in receiving agricultural information from ICT based media. Hassan *et al.* (2008) studied the use of Information and Communication Technology (ICT) among Agro-based entrepreneurs in Malaysia and revealed that farmers do not know the benefits of using ICT, have no skill in using ICT, lack of time to use ICT, difficulty in using ICT, and have no knowledge in using ICT are the five most problems and obstacles faced by farmers in using ICT.

Despite the good accuracy of the model used in IPDDS, desired effectiveness may not be found due to the obstacles. For improving the effectiveness of IPDDS at the field level among the user, these issues are to be taken into consideration by a policymaker, planner, system designer, and developer.

4.6 Suggestions of the Users for Improving IPDDS and Development of an Improved Model for IPDDS

4.6.1 Suggestions of the Users for Improving IPDDS

Attempts were taken to seek suggestions from the respondents against each obstacle to mitigate them. To improve IPDDS, users provided overall suggestions and they also provided suggestions against each item of obstacle to mitigate them. Suggestions against each item of the obstacle faced by the farmer in using IPDDS presented in Table 4.27. The word cloud of suggestions is also presented in Figure 4.6. Some of the suggestions were found to come frequently from several respondents. Suggestions were recorded and processed in word clouds using word mapping online software (Zygomatic, 2021). Textual analysis only showed the count of tag words or key words. The counts or frequency of unique key words were matched with the suggestions provided by the farmers and thus the frequency of a specific suggestion were determined. The respondent demanded the key words as suggestions to be incorporated in the IPDDS.

Table 4.27 Obstacles and user-provided suggestions to mitigate the obstacles

Sl. no.	Items of obstacle	Suggestions
A. Socio-economic obstacles		
1	Illiteracy	Voice interactive system (124), intelligent system (112), simplifying advice (14), easy language (13), no password, pictorial interface, adding video footage, calling option
2	Unavailability of smart phone	Connecting respondents with Union Digital Centers (UDC) and Agriculture Information and Communication Center (14), ensuring shared access, helpline (3)
B. Technical obstacles		
3	Lack of sufficient internet speed	Off-line system (145), comparison system (70),
4	Need technical knowledge to use IPDDS	Farmers' training (146), campaigning(29), demonstration, calling option, brand name with a group name (2), per decimal application rate, image uploading option(31), feedback system(13)
5	Inadequate extension service to support the use of IPDDS	Farmers' training (46), campaigning (29), involving Sub-Assistant Agriculture Officer (SAAO) (3), demonstration
6	Can't detect disease at an early stage	Covering all stages of disease (220), intelligent system (11), comparison system (10), more accuracy, clear image, image uploading option (31)
7	Presence of multiple diseases in the same plant	comparison system(110), image uploading option(61)
8	Presence of the background of the image	Intelligent system (111), comparison system (80), image uploading option (31)
C. Psychological obstacles		
9	Apathy to use IPDDS	Farmer's training (125), campaigning (99), awareness building (45), motivation (16)
10	ICT phobia	Farmer's training (115), campaigning (29), awareness building (5)

Numerical figures in the parentheses indicate the frequency of the suggestions of the users of IPDDS.

In the word cloud, the word having bigger size indicates greater frequency and importance of the suggestion. Zhang *et al.* (2016) used word cloud for textual analysis of the response of the respondent in studying way of measuring IT effectiveness.

Fig. 4.6 Word cloud of suggestions showing the comparative importance of the suggestions provided by the users to improve IPDDS

Data in Table 4.27 and Figure 4.6 revealed that important and frequently suggested suggestions were covering all stages of disease, off-line system, farmers' training, voice interactive system, intelligent system, comparison system and image uploading option etc.

4.6.2 Development of an improved model for IPDDS as per suggestions of the users

Based on the findings of the study an improved model was proposed. Obstacles faced by the user farmers for detecting plant diseases, their suggestions to mitigate the obstacles, and insight of the researcher were taken into considerations. This is a functional model. This model focus on policy implication rather than an architectural model. It provides a functional way of developing multipurpose IPDDS that can be developed and improved gradually at low cost with low resources. The researcher emphasized the system-user interaction and user-friendliness. model is presented in Figure 4.7.

4.6.2.1 Development of the system

A user-friendly Automated Image-based Plant Disease Detection System (AIPDDS) can be developed through the integration of a well-trained efficient neural network-based model or other state-of-the-art techniques with android or other platforms. Sufficient image data should be used to train the model for reasonable accuracy of the system. Available plant image datasets can be used or images can be collected from the field.

4.6.2.2 Database enrichment and updating the system

When the system found a new disease that is not included in the database of AIPDDS, it will be a new learning for the system. The disease will be included as a new class through supervised learning. The database can be enriched by the target user (field level extension service provider and/ or advanced level farmer). When the new class attains a reasonable accuracy through database enrichment and training of the model, AIPDDS will be updated as shown in figure 4.1. Users will be able to get the updated service on updating the application.

4.6.2.3 Major features of the model

Usability in both online and offline mode: This model proposed both offline and online service delivery options. According to the model, the proposed IPDDS will be consist of two major databases: image database and advisory database. A part of the image database should be accessible in off-line mode for the users - crop-wise and disease-wise so that users can use it to compare their plant's disease to identify visually and get advice from the advisory database. If users fail to identify the disease, then they will be connected to the internet. After submission of the image to the server of AIPDDS, they will get an advisory on the detection of the disease. The system will receive the image with GPRS data so that the data can be used for another purpose in the future.

Wide accessibility: This study proposed framework to be voice command interactive so that users can operate it through vice command and advice also be found in a voice as well as text.

Intelligent system: The system should be as much intelligent that can identify disease at an early stage of disease commencement. Identification of disease at an early stage of disease commencement is crucial for reducing farmers' yield loss. Most of the systems available for plant disease detection are not capable of detecting disease at an early stage of disease commencement. To ensure this, a single disease can be classified into several classes. So that it covers all important stages of disease development.

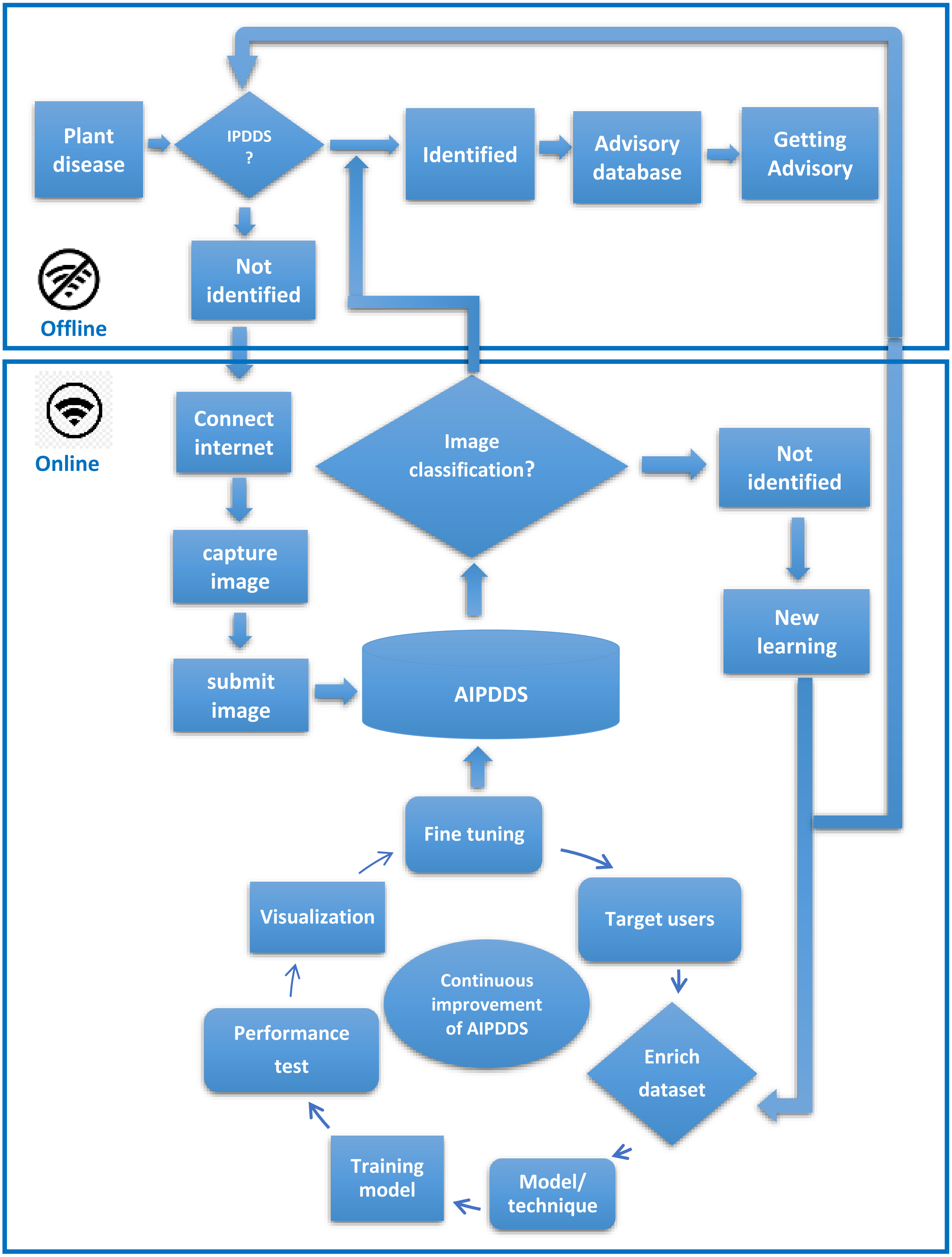

Fig. 4.7 Proposed functional model for improving DPPIS

Interactive interface: Techniques available for developing IPDDSs are not at such an intelligent level yet that can provide 100% accurate advice as farmers needed, therefore the system must have an interactive interface to share current field problems and expert opinions in real-time.

4.6.2.4 Scope of using the model

There are several scopes of using the framework in different purposes like-

Plant disease detection: The primary objective of the proposed model for IPDDS is to detect plant disease to protect crops from yield loss.

Field crop monitoring: As the image data will be collected with General Packet Radio Service (GPRS) data, the geographical distribution of disease incidence can be observed through managing the data in a dashboard.

Disease forecasting: Aligning the GPRS data, the geographical distribution of disease incidence, and weather data disease prediction can be modeled. This model can be used in disease forecasting to make farmers aware of the disease well ahead of disease commencement.

Localized use of resources: This model gives a guideline to develop local IPDDS using local resources. Own data set can be created so that more accuracy can be found by using even local small datasets with variation.

Although there are a good number of IPDDS working well, farmers faced several obstacles in IPDDS. The rank order of the obstacle item indicates that for improving the effectiveness of IPDDS at field level among the user, issues to be taken into consideration are- illiteracy among the farmer, inability of disease detection at an early stage, unavailability of smartphone, ICT phobia, inadequate extension service to support the use of IPDDS, lack of sufficient internet speed, apathy to use IPDDS, need technical knowledge to use IPDDS, presence of multiple diseases in same plant and presence of background of the image. The obstacles are not addressable by a single means. Some of them are to be addressed at the development stage, some at the planning stage, and some of them are to be addressed at the policy level through implementing programs for increasing farmer’s capacity and infrastructure facilities. The proposed functional model is desired to help in improving IPDDS overcoming the relevant obstacles.

CHAPTER 5

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

5.1.1 Introduction

The use of Information and Communications Technology (ICT) and the understanding of its potentials to transform farming from labor–intensive to smart automated farming are increasing significantly among the farming community. Plantix – an Image-based Plant Disease Detection System (IPDDS) has been installed more than 15 million as of 9 November 2021 (GmbH, 2021). IPDDS is a system where images are used to detect plant diseases. Several smartphone applications are available and are being used by farmers, gardeners, and agricultural advisory service providers. A farmer or user can use an image library to identify plant disease or upload images to identify plant disease using these applications.

Agriculture has graduated from agriculture 1.0 to agriculture 4.0 resembling industry 4.0 and smart farming is the reality of agriculture 4.0. These gradual developments in the field of agriculture and the reality of agriculture 4.0 and onward or smart agriculture indicate the gravity of the intervention of ICT in the agricultural sector. One of the major concerns of industry 4.0 and hereby agriculture 4.0 is that the use of the automated system will be increased and human labor involvements will be reduced. In these circumstances, the need for machine learning or artificial neural network, or artificial intelligence-based IPDDS will just widen the space for agriculture 4.0 and onward.

FAO has considered 'Agricultural productivity and innovation' and 'Transboundary pests and diseases' as two major drivers of change in agriculture in 21st century. Bangladesh has recently graduated from Least Developed Country (LDC) to developing country through the acceptance of the proposal in the United Nations (UN) general assembly in 2021. Still, the country has to fight against several constrains. Constrains of inadequate supply of pesticides are associated with infestation of pests and diseases etc. Although Bangladesh has got very grass root level agricultural extension services, the farmer often suffered from a lack of information and advice during the infestation. Strengthening MIS and ICT-based knowledge management systems and e-agriculture has been taken as a strategy for developing the agriculture sector of Bangladesh in the Bangladesh Eighth Five Year Plan (July 2020-June 2025). Bangladesh has also taken an action plan for increasing women and youth participation in agriculture. Making those plan successful, the use of ICT-based knowledge management systems like IPDDS is a must.

Considering the general background, global and Bangladesh perspectives it can be said that the use of knowledge-based technology like IPDDS is irresistible. Now the question is how it can be made more feasible in terms of effectiveness. This study believes that the findings of the study will show a path for the policymakers, IT industry, and agriculture extension personnel to solve the question.

Objectives of the Study

To shape the research in a manageable and meaningful way, the following objectives are specified:

- ❖ To determine the purpose of using IPDDS and to describe the Profession, Gender, and Geographical regions of the IPDDS users
- ❖ To determine the effectiveness of IPDDS as perceived by the users
- ❖ To determine the characteristics of the IPDDS users
- ❖ To explore the contribution and effects of the selected characteristics of the users to/on their perceived effectiveness of the IPDDS
- ❖ To compare the benefits obtained by using IPDDS and obstacles faced in using IPDDS
- ❖ To develop a functional model for improving IPDDS as per the suggestions of the users

5.1.2 Materials and Methods

IPDDS is used throughout Bangladesh. A list of 8911 registered users was collected from the Department of Agricultural Extension (DAE), which constituted the study population. The sample size was determined using a sample size calculator developed by Creative Research Systems as 384 with 95% confidence level and 5 as a confidence interval. A case study was conducted titled ‘Image-based plant disease detection system- an experience of Bangladesh’ to find the effectiveness of Krishoker Janala as perceived by the user and to get about the items to be used in the research. After case study and consultation of literature and related experts, 14 Independent (Causal) variables and one dependent variable. The 14 selected characteristics of the users were considered as independent variables of the study and these were (a) personal characteristics - age, education, farming experience, use of ICT; (b) socio-economic and characteristics – crop farm size, annual crop production income, time saved, cost saved, visit saved and individual extension contact and (c) professional characteristics - knowledge on plant disease management, use of IPDDS, obstacles faced in using IPDDS and benefits obtained by using IPDDS. Effectiveness IPDDS constituted the dependent variable of the study. Required items were collected, analyzed and necessary scale were developed and finally, an interview schedule was prepared. Validity and reliability of scales and interview schedule were tested. Data were collected from the respondents by telephone interviewing during the period from May 01, 2021 to September 30, 2021 by the researcher himself using the interview schedule for the study. IBM SPSS Statistics 20 was used for data analysis. Descriptive statistical measures including number and percentage distribution, range, mean, standard deviation and co-efficient of variance were used for describing both the independent and dependent variables. Rank order was made whenever necessary. Tables were also used in presenting data for clarity of understanding.

Initially, Spearman’s rank correlation was run to determine the relationship of the selected characteristics of the users with their perceived effectiveness of IPDDS. Full model regression analysis was also done. Due to misleading results from multi-collinearity, stepwise multiple regression was used by involving significant independent variables after the correlation test to find out the contribution of the independent variables to the dependent variable. Finally, path analysis was done to find out the indirect effects of the independent variables separately on the dependent variable. A five percent (0.05) level of probability was used as the basis for rejection of any null hypothesis throughout the study. Co-efficient values significant at 0.05 level are indicated by one asterisk (*), and that at 0.01 level by two asterisks (**) and at 0.001 level or above by three asterisks (***). For determining comparative effectiveness of the items, rank orders were made based on the descending order of the Standardized Effectiveness

Index (SEI), Standardized Use Index (SUI), Standardized Benefit Index (SBI) and Standardized Obstacle Faced Index (SOFI) for comparing effectiveness, use, benefits and obstacles of IPDDS respectively. Suggestions from the respondent to mitigate the obstacles were sought against each items of obstacles and analyzed using word mapping online software (Zygomatic, 2021) and a model for improving IPDDS was developed.

5.1.3 Results and Discussion

5.1.3.1 Purpose of using IPDDS, Profession, Gender, and Geographical regions of the users

Purpose of using IPDDS: IPDDS is mostly used for detecting plant diseases. But the users' specific purposes were varied as own farming, farm supporting, service purpose, business purpose, rooftop gardening, service and farming, business and farming, and study purpose. Findings showed that according to the purpose of use, a user of IPDDS in percent own farming (44) ranked first followed by farm supporting (34), service and farming (6.8), business and farming (4.4), service purpose (3.6), rooftop gardening (3.2), study (2.0) and business purpose (2.0). The findings indicate that IPDDS is mostly used in own farming.

Profession of the users: IPDDS is used for various purposes. Beside farmer, govt. service holder, private service holder, businessman and student were found to use IPDDS. According to the profession of user of IPDDS in percent Farmer (36) ranked first followed by private service holder (18.8), businessman (17.2), student (16), and Govt. service holder (12). This is an indication of being IPDDS used by a wide range of professionals.

Gender of user: An overwhelming majority **(**97.92) of the users are male and only 2.08% user are female.

Geographical regions of user: According to distribution of user in percent Dhaka region ranked first (15.2) followed by Rangpur (13.6), Dinajpur (13.2) Rajshahi (10.0), Bogra (8.8), Jashore (8.4), Mymensingh (6), Cumilla (5.2), Khulna (4.8), Sylhet (3.2), Chattogram (2.8), Barisa (2.8), Faridpur (2.4) and Rangamati (1.6).

5.1.3.2 Effectiveness of IPDDS

Effectiveness of IPDDS was the main focus of the study. The observed effectiveness of using IPDDS score of the user respondents ranged from 14 to 65 against the possible range of 0-66.

The mean score was 38.84 with the standard deviation of 9.221 and Co-efficient variance of 22.32%. Most of the users (77.90%) were in a perception that IPDDS is moderately effective while 19.50% user are in a perception that IPDDS is highly effective and 2.60% were in a perception that IPDDS was less effective in getting plant disease-related services.

Dimension wise comparison of the effectiveness of IPDDS: Based on ASEI 'User satisfaction' ranked first followed by 'system accuracy', 'user friendliness', 'content quality', 'device responsiveness' and 'offline usability'

Item wise comparison of the effectiveness of IPDDS: Findings revealed that according to descending order of Effectiveness Index (EI), 'on-time service' ranked first followed by 'time needed for getting service', 'service cost', 'delivery of the service', 'ease of the system', 'proper identification of plant disease', 'smoothly working system', 'negligible error in the system', 'usefulness of content', 'easy to use', 'lower device hanging tendency', 'comfort to use', 'lower size of the software', 'off-line running', 'easy to remember how to use', 'off-line sharing' 'off-line installation', 'validity of content', 'running in any smart device' platform operability', 'updated content' and 'requirement of lower processor'.

Benefits obtained by the users by using IPDDS: Findings revealed that according to descending order of Standard Benefit Index (SBI), 'Reduce time for detecting disease' ranked first followed by 'Increase service accessibility', 'Increase service quality', 'Increase respondents' knowledge', 'Reduce disease detecting cost', 'Increase quality of produces', 'Increase production', 'Increase net income' and 'Reduce pesticide use'. Benefit items are discussed below in ascending order.

Obstacles faced by the users in using IPDDS: According to descending order of SOI 'illiteracy', ranked first followed by 'inability of disease detection at an early stage', 'unavailability of the smart phone', 'ICT phobia', 'inadequate extension service to support the use of IPDDS', 'lack of sufficient internet speed', apathy to use IPDDS', 'need technical knowledge to use IPDDS', 'presence of multiple diseases in same plant' and 'presence of background of the image'.

Suggestions of users for improving IPDDS: Against all the obstacles, users suggested for its improvement. Frequently suggested suggestions by the users included- covering all stages of disease, farmers' training, off-line system, comparison system, voice interactive system, intelligent system, comparison system, image uploading option etc.

Improved framework of IPDDS as per suggestions of the users: Based on the findings of the study an improved framework was proposed. Obstacles faced by the user farmer for detecting plant diseases, their suggestions to mitigate the obstacles, and insight of the researcher were taken into considerations. This is a functional model. This model focus on policy implication rather than an architectural model. It provides a functional way of developing multipurpose IPDDS that can be developed and improved gradually at low cost with low resources. Major features and scopes of the framework are- usability in both online and offline mode, wide accessibility, intelligent system, interactive interface, plant disease detection, field crop monitoring, disease forecasting, localized use of resources.

5.1.3.3 Characteristics profile of the users

Age: An overwhelming majority (86.70%) of the IPDDS users were young compared to 10.40 percent being middle aged and 2.90 percent old.

Education: The highest proportion (68.0%) of the IPDDS users had tertiary level of education, compared to 20.6 percent higher secondary education level, 10.20 percent secondary level of education and 1.30 percent primary level of education. These finding indicated that cent percent (100%) of the respondents were literate with primary to tertiary level of education.

Use of ICT: About two-third (65.90%) of the respondent were moderate users of ICT, compared to 28.60 percent high user of ICT and 12.80 percent low user. Findings again revealed that overwhelming majority (94.5%) of the users were medium to high users of ICT.

Farming experience: An overwhelming majority (87.50%) of the users had medium farming experience, compared to 11.20 percent had long and 1.30 percent had short farming experience.

Crop farm size: The highest proportion (45.8 percent) of the IPDDS user respondents had small crop farm size while 25.3 percent and 15.9 percent had medium and marginal farm size respectively. The rest 6.3% of the respondent had large farm size.

Annual crop production income: Most of the users (65.60 percent) had medium income compared to 25.5% of the users had high income, 8.90 percent had low income from crop production.

Time saved: Most of the users (70.60 percent) saved medium time compared to 15.60% of the users saved low time and 13.80 percent saved high time for detecting plant diseases by using IPDDS.

Cost saved: Most of the user (75.80 percent) saved medium cost compared to 13.00% of the users saved high cost and 11.20 percent saved low cost by using IPDDS for detecting plant disease.

Visit saved: Most of the users (65.60 percent) saved medium visit compared to 28.40% of the users saved low visit and 6.0 percent saved high visit by using IPDDS for detecting plant disease.

Individual extension contact: Majority (69.3%) of the users had medium extension contact, compared to 16.7 percent having high extension contact and 14.10 percent had low individual extension contact. Findings again revealed that more than two-third (86.00%) of the users had medium to high individual extension contact.

Knowledge on plant disease management: The majority (66.4%) of the users had medium knowledge compared to 21.6 percent had high knowledge and 12.0 percent had low Knowledge on plant disease management. Findings again revealed that Overwhelming majority (82.0%) of the users had medium to high knowledge on plant disease management.

Use of IPDDS: About two-third (63.5%) of the users had medium use compared to 22.9 percent had low use and 13.5 percent had high use of IPDDS. Findings again revealed that te overwhelming majority (77.00%) of the users had medium to high use of IPDDS. Based on Standardized Use Index (SUI), 'Krishoker Janala' ranked first followed by 'Plantix' and 'Plant Doctor'. No other IPDDS found to be used in Bangladesh.

Benefits obtained by using IPDDS: The highest proportion (74%) of the respondents belonged to the group obtaining medium benefits by using IPDDS, while 10.4% and 15.6% belonged to the group obtaining low and high benefits by using IPDDS respectively. Thus, overwhelming majority (89.6 %) of the users obtained medium to high benefits by using IPDDS.

Obstacles faced in using IPDDS: The highest proportion (74.00%) of the users faced medium obstacles in using IPDDS compared to 15.6% and 10.40% having high and low obstacles in using IPDDS respectively. It means that Overwhelming majority (84.4%) of the users faced medium to high obstacles in using IPDDS.

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5.1.3.4 Contribution and Effect of the Selected Characteristics of the Users to/on Their Perceived Effectiveness of IPDDS

Contribution of the selected characteristics of the users to the perceived effectiveness of IPDDS: Step-wise multiple regression analysis indicated that four (4) selected characteristics of the IPDDS users such as 'time saved', 'knowledge on plant disease management', 'benefits obtained by using IPDDS' and 'use of ICT had significant positive contribution and one (1) variable namely 'Obstacles faced in using IPDDS' had significant negative contribution to their perceived effectiveness of IPDDS. The whole model of five (5) variables explained 34.5 percent of the total variation to the effectiveness of IPDDS. Since the standardized regression coefficients (Beta weight) of four (5) variables formed the equation and were significant, it might be assumed that whatever contribution was there, it was due to these five (5) variables.

Indirect effects of the selected characteristics of the users on the perceived effectiveness of using IPDDS: Path coefficient analysis indicated that each of the five (5) contributing variables had total indirect effects through other four (4) variables to the effectiveness of IPDDS ranging from 0.03 to 0.11.

5.1.3.5 Comparative Benefits Obtained and Obstacles Faced in Using IPDDS

Benefits obtained by using IPDDS: According to the descending order of Standard Benefit Index (SBI), 'reduce time for detecting disease' ranked first followed by 'increase service accessibility', 'increase service quality', 'increase respondents' knowledge', 'reduce disease detecting cost', 'increase quality of produces', 'increase production', 'increase net income' and 'reduce pesticide use'.

Obstacles faced by the farmer in using IPDDS: According to the descending order of Standardized Obstacle Index (SOI) 'illiteracy', ranked first among the items of obstacles followed by 'inability of disease detection at an early stage', 'unavailability of the smart phone', 'ICT phobia', 'inadequate extension service to support the use of IPDDS', 'lack of sufficient internet speed', apathy to use IPDDS', 'need technical knowledge to use IPDDS', 'presence of multiple diseases in same plant' and 'presence of background of the image'.

5.1.3.6 Suggestions of the Users for Improving IPDDS and Development of an Improved Model for IPDDS

Attempts were taken to seek suggestions from the respondents against each obstacle to mitigate them. To improve IPDDS, users provided overall suggestions and they also provided suggestions against each item of obstacle to mitigate them. Frequently suggested suggestions were covering all stages of disease, off-line system, farmers' training, voice interactive system, intelligent system, comparison system and image uploading option etc.

Development of an improved model for IPDDS as per suggestions of the users: Based on the findings of the study an improved model was proposed. Obstacles faced by the user farmers for detecting plant diseases, their suggestions to mitigate the obstacles, and insight of the researcher were taken into considerations. The model focus on policy implication rather than an architectural model. It provides a functional way of developing multipurpose IPDDS that can be developed and improved gradually at low cost with low resources. The researcher emphasized the system-user interaction and user-friendliness. Major features of the model include -usability in both online and offline mode, wide accessibility, intelligent system, interactive interface etc. The model poses several scopes like -plant disease detection, field crop monitoring, disease forecasting, localized use of resources. This model gives a guideline to develop local IPDDS using local resources. Own data set can be created so that more accuracy can be found by using even local small datasets with variation.

5.2 Conclusions

Based on the findings, discussion and logical interpretation, the following conclusions were drawn:

i. IPDDS was used by a wide range of professional such as farmers (36%), private service holders (18.8%), businessmen (17.2%), students (16%), and government service holders (12%) for a wide range of purposes like - own farming (44%), farm supporting (34%), service and farming (6.8%), business and farming (4.4%), advisory service (3.6%), roof top gardening (3.2%), study and business (2.0%) and the user are scattered in all the regions of Bangladesh. Therefore, it can be concluded that IPDDS has a potentiality to reach agricultural advisory services among a wide range of people.

ii. Overwhelming majority (80.5%) of the users perceived that IPDDS was low to moderate effective to detect plant diseases and getting plant diseases-related services and rest 19.50% users perceived IPDDS as highly effective tool for detecting plant diseases and getting related services. Therefore, conclusion can be drawn that there is still scope to make it more effective.

iii. According to descending order of Standardized Effectiveness Index (SEI), 'on-time service' ranked first among the items of effectiveness followed by 'time needed for getting service', 'service cost', 'delivery of the service', 'ease of the system', 'proper identification of plant disease' etc. Therefore, it may be concluded that these points are important determinant for the effectiveness of IPDDS.

iv. Most of the users (70.60 percent) saved medium time compared to 15.60% of the users saved low time and 13.80 percent saved high time for detecting plant diseases by using IPDDS. Step-wise multiple regression analysis indicated that the 'time saved' by the users in detecting plant disease had significant positive contribution to their perceived effectiveness of IPDDS. ‘Time saved’ of the users had indirect effect through ‘knowledge on plant disease management’, ‘benefits of using IPDDS’, ‘use of ICT’ and ‘obstacles faced in using IPDDS on their perceived effectiveness of IPDDS. Therefore, it may be logically concluded that the users saved more time in detecting plant disease by using IPDDS perceived more effectiveness of IPDDS.

v. Overwhelming majority (82.0%) of the users had medium to high knowledge on plant disease management. Step-wise regression showed that ‘knowledge on plant disease management’ of the users had significant positive contribution to their perceived effectiveness of IPDDS. ‘Knowledge on plant disease management’ of the users had indirect effect through ‘time saved’, ‘benefits of using IPDDS’, ‘use of ICT’ and ‘obstacles faced in using IPDDS’ on their perceived effectiveness of IPDDS. It may be inferred that other variables remaining constant, knowledge on plant disease management had an influence on the effectiveness of using IPDDS and was a determinant of the effectiveness of using IPDDS.

vi. Overwhelming majority (94.5%) of the users were medium to high users of ICT. ‘Use of ICT’ of the users had significant positive contribution to their perceived effectiveness of IPDDS. ‘Use of ICT of the users had indirect effects through ‘time save’, ‘knowledge on plant disease management’, ‘benefits of using IPDDS’ and ‘obstacles faced in using IPDDS’ on their perceived effectiveness of IPDDS. It may be inferred that other variables remaining constant, the use of ICT of the users had an influence on the effectiveness of using IPDDS and was a determinant of the effectiveness of using IPDDS.

vii. Majority (84.4%) of the users faced medium to high obstacles in using IPDDS. ‘Obstacles faced in using IPDDS’ had significant negative contribution to their perceived effectiveness of IPDDS. ‘Obstacles faced in using IPDDS’ had indirect effects through ‘Use of ICT’, ‘time save’, ‘knowledge on plant disease management’ and ‘benefits of using IPDDS’ on their perceived effectiveness of IPDDS. It may be inferred that other variables remaining constant, ‘Obstacles faced in using IPDDS’ had negative influence on the effectiveness of using IPDDS and was a determinant of the effectiveness of using IPDDS. According to descending order of Standardized Obstacle Index (SOI) ‘illiteracy’, ranked first item of obstacles followed by ‘inability of disease detection at an early stage’, ‘unavailability of the smart phone’, ‘ICT phobia’, ‘inadequate extension service to support the use of IPDDS’ etc. Therefore, it may be concluded that items of benefits and obstacles are to be taken into consideration to minimize the obstacles for increasing the effectiveness of IPDDS.

viii. Based on the suggestions of the users to minimized the obstacles of using IPDDS, a model of IPDDS is proposed to focus on policy implication rather than an architectural model. It provides a useful way of developing multipurpose IPDDS that can be developed and improved gradually at low cost with low resources. The researcher emphasized the system-user interaction and user-friendliness. Major features of the model include -usability in both online and offline mode, wide accessibility, intelligent system, interactive interface etc. The model poses several scopes like -plant disease detection, field crop monitoring, disease forecasting, localized use of resources. This model gives a guideline to develop local IPDDS using local resources. Own data set can be created to find more accuracy by using even local small datasets with a variation. Therefore, it can be concluded that the proposed model has the potential to be used in agriculture for better agricultural advisory services.

5.3 Recommendations

5.3.1 Recommendations for policy implication

i. IPDDS was used by a wide range of professional such as farmers, private service holders, businessmen, students, and government service holders for a wide range of purposes like - own farming, farm supporting, service and farming, business and farming, advisory service, roof top gardening, study and business and the user are scattered in all the regions of Bangladesh. Overwhelming majority (84.1%) of the users perceived that IPDDS was low to moderate effective to detect plant diseases and getting plant diseases related services. Therefore, it can be recommended that IPDDS should be extended for better agricultural advisory services with its improvement.

ii. Both IT-industry and policy formulating authority should take steps to improve the effectiveness of IPDDS.

iii. Standardized Effectiveness Index (SEI) of the items were varied. Therefore, it may be recommended that attempts should be taken to improve the IPDDS for increasing the effectiveness of all the items. Therefore, steps should be taken by the authority to improve the items having low SEI.

iv. 'Time saved' by the users in detecting plant disease had significant positive contribution to their perceived effectiveness of IPDDS. Therefore, it may be recommended that IPDDS is need to be prepared in such a mode that the users can save their valuable time to detecting plant disease and to get related information in time.

v. 'Knowledge on plant disease management' of the users had significant positive contribution to their perceived effectiveness of IPDDS. Therefore, it may be recommended that agricultural advisory service providing organizations should provide necessary training to improve the knowledge of the farmers on plant disease management so that they could use IPDDS effectively to detect plant diseases and to get related information.

vi. 'Use of ICT' of the users had significant positive contribution to their perceived effectiveness of IPDDS. Therefore, it may be recommended that agricultural advisory service providing organizations should take necessary motivational campaigning for the farmers and to provide necessary ICT tools so that they could use IPDDS effectively to detect plant diseases and to get related information.

vii. 'Obstacles faced in using IPDDS' had significant negative contribution to their perceived effectiveness of IPDDS. Out of the obstacles in using IPDDS, 'inability of disease detection at an early stage', 'presence of multiple diseases in same plant' and ‘presence of background of the image’ are related to the development of IPDDS while the rest of them are related to policy implication. Therefore, it is recommended that IPDDS should be improved through developing IPDDS overcoming ‘inability of disease detection at an early stage’, ‘presence of multiple diseases in same plant’ and ‘presence of background of the image’ obstacles. Remaining issues to be addressed at the policy level through implementing programs for increasing farmer’s capacity and infrastructure facilities and advisory service providing organizations should take necessary actions so that the farmers could get better benefits.

viii. The proposed model provides a useful way of developing multipurpose IPDDS that can be developed and improved gradually at low cost with low resources. Therefore, agricultural policy makers, IT industries, start-ups and entrepreneurs should come forward to implement the proposed model for improving IPDDS.

5.3.1 Recommendations for future works

The concept of IPDDS is comparatively new and technologies used in this case are rapid changing. Therefore, this study recommends some future works like:

- ✓ Factors of the farmers were many and varied, but in the present study only 14 factors on personal, socio-economic and psychological aspects were taken into consideration. As features and scopes of ICT interventions change rapidly over time, further research should be conducted involving other variables.
- ✓ This study just found out the suggestion of farmers for improving IPDDS and took into account some of them to develop a model for improvement. There are ample scopes of more research on suggestions provided by the farmer.
- ✓ The scope of integrating IPDDS with Agricultural Decision Support System (ADSS) to make farmers enable to take the right decision on any issue of growing crop at any time can be studied.
- ✓ Effectiveness of the proposed functional model for improving DPPIS needs to be studied further from farmers’ perspectives.

- ✓ Determining the features of IPDDS influencing effectiveness among the farmers and their contributions to the effectiveness of IPDDS needs to studied.
- ✓ Comparison on the user of IPDDS and non-user of IPDDS in respect of knowledge on plant disease management, problems faced in plant disease management, annual income etc. can be studied.

References

Adama Business. (2021). *ADAMA Bullseye* (version 1.6.1) [Mobile app] [Accessed 26 Dec. 2021]https://play.google.com/store/apps/details?id=com.adama.adamabullseyeandhl=en_USandgl=US

AeroTech Studios. (2021) *Plant Doctor* (version 1.1) [Mobile app] [Accessed 26 Dec. 2021]. https://play.google.com/store/apps/details?id=organisation.tensorflow.litee.examples.classification.plantandhl=en_USandgl=US

Ajzen, I. (1985). From Intentions to Actions: A Theory of Planned Behavior. In J. Kuhl and J. Beckmann (Eds.), *Action Control: From Cognition to Behavior*. Springer. pp. 11–39. https://doi.org/10.1007/978-3-642-69746-3_2

Alam, M., and Wagner, C. (2013). Assessing the Impact of Digital Procurement via Mobile Phone on the Agribusiness of Rural Bangladesh: A Decision-analytic Approach. *Agribusiness and Info. Mgnt.*, *5*:31–41.https://doi.org/10.14771/AIM.5.1.4

Aldosari, F., Shunaifi, M. S. A.,Ullah, M., A., Muddassir, M., Noor, M., A. (2019) Farmers' perceptions regarding the use of Information and Communication Technology (ICT) in Khyber Pakhtunkhwa, Northern Pakistan, *J. Saudi Soc. Agric. Sci. 18*(2):211-217, https://doi.org/10.1016/j.jssas.2017.05.004.

Ali, M., Mubeen, M., Hussain, N., Wajid, A., Farid, H., Awais, M., Hussain, S., Amin, A., Akram, R., Imran, M., Ali, A., and Jatoi, W. (2019). Role of ICT in Crop Management In: Hasanuzzaman M. (eds) Agronomic Crops. Springer, Singapore. (pp. 637–652). https://doi.org/10.1007/978-981-32-9783-8_28

Ali, M. S. (2008). Adoption of Selected Ecological Agricultural Practices by the Farmers. Ph.D (Ag. Ext. Ed.) Thesis. Dept. of Agric. Extn. Edn., Bangladesh Agricultural University, Mymensingh.

Alrubaiee, Gamil. (2019).*Re: Can Standard Deviation (SD) be greater than MEAN?*Retrieved from:https://www.researchgate.net/post/Can-Standard-Deviation-SD-be-greater-than MEAN/5e07a1712ba3a1dd554911c5/citation/download.

Andress, J., and Winterfeld, S. (2014). Chapter 1—What is Cyber Warfare? In J. Andress and S. Winterfeld (Eds.), *Cyber Warfare (Second Edition)* (pp. 1–17). Syngress. https://doi. org/10.1016/B978-0-12-416672-1.00001-5

Arsenovic, M., Karanovic, M., Sladojevic, S., Anderla, A., and Stefanovic, D. (2019). Solving Current Limitations of Deep Learning Based Approaches for Plant Disease Detection. *Symmetry*, 11(7), 939. https://doi.org/10.3390/sym11070939

Ashqar, B., and Abu-Naser, S. (2019). Image-Based Tomato Leaves Diseases Detection Using Deep Learning. *Int. J. of Eng. Res.*, *2*:10–16.

Atila, U., Uçar, M., Akyol, K., and Uçar, E. (2021). Plant leaf disease classification using EfficientNet deep learning model. *Ecol. Inform.*, *61*, 101182. https://doi.org/10.1016/j.ecoinf.2020.101182

Bansal, P., Kumar, R., and Kumar, S. (2021). Disease Detection in Apple Leaves Using Deep Convolutional Neural Network. *Agric*, *11*(7), 617.

Barbedo, J. (2016). A review on the main challenges in automatic plant disease identification based on visible range images. *Biosyst. Eng.*, *144*:52–60. https://doi.org/10.1016/j.biosystemseng.2016.01.017

Bangladesh Bureau of Statistics. (2018a). *Statistical Yearbook Bangladesh* (38th Edition). Statistics and Informatics Division (SID), Ministry of Planning, Government of the People's Republic of Bangladesh, www.bbs.gov.bd ISBN978-984-475-020-3

Bangladesh Bureau of Statistics. (2006b). *Statistical Pocketbook Bangladesh.* Planning Division, Ministry of planning, Government of the People's Republic of Bangladesh.

Bloom, B. S. (1956). Taxonomy of educational objectives: The classification of educational goals. Longmans, London, UK.

Boulent, J., Foucher, S., Théau, J., and St-Charles, P.-L. (2019). Convolutional Neural Networks for the Automatic Identification of Plant Diseases. *Front. Plant Sci.*, *10*, 941. https://doi.org/10.3389/fpls.2019.00941

Brennan, R. L. (1972). A Generalized Upper-Lower Item Discrimination Index. *Educ. Psychol. Meas.*, *32*(2): 289–303. https://doi.org/10.1177/001316447203200206

Camargo, A., and Smith, J. S. (2009). An image-processing based algorithm to automatically identify plant disease visual symptoms. *Biosyst. Eng.*, *102*(1):9–21.

Chin, J., Diehl, V., and Norman, K. (1988). Development of a Tool Measuring User Satisfaction of the Human-Computer Interface. Paper Presentation at Sig Chi'88 https://doi.org/10.1145/57167.57203

Codex Software Solution Ltd. 2017. *Krishoker janala* (version 1.2) [Mobile app] [Accessed 26 Dec2021].https://play.google.com/store/apps/details?id=com.dhdel.codex.krishokerjanala

Codex Software Solution Ltd. 2020. *Krishoker janala* (version1.7) [Mobile app] [Accessed 26Dec.2021].https://play.google.com/store/apps/details?id=com.dhdel.codex.krishok erjanala

Cohen, R. J., Swerdlik, M. E and Edward, D. S. (2012). Psychological Testing and Assessment: An Introduction to Tests and Measurement (8th edition). McGraw-Hill Education.

Coombs, C. H. (1950). The Concepts of Reliability and Homogeneity. *Educ. Psychol. Meas*. *10*(1):43-56. doi:10.1177/001316445001000103

Creative Research Systems. (2021). Sample Size Calculator [Survey Software] [Accessed 12August 2021] https://www.surveysystem.com/sscalc.htm

Cruz, A., Luvisi, A. De B., Luigi, Ampatzidis, Y. (2017). Vision-Based Plant Disease Detection System Using Transfer and Deep Learning. *Asabe Annu. Int. Meet.* Washington, USA, doi:10.13031/aim.201700241

DAE. (2017). *Agricultural Extension Manual*. Department of Agricultural Extension, Ministry of Agriculture, Government of the People's Republic of Bangladesh http://www.dae.gov.bd/sites/default/files/files/dae.portal.gov.bd/publications/f39d9608_396b_48c9_bf9e_a3df2183d2fe/2020-08-07-20-39 c25460ef7d6a342a2622c4ffc4ca2a47.pdf

Das, D., Singh, M., Mohanty, S. S., and Chakravarty, S. (2020). Leaf Disease Detection using Support Vector Machine. *Int. Conf. Comm. Sig.Proc. (ICCSP)*:1036–1040.

Das, U., Ansari, M. A., Kameswari, V., and Bhardwaj, N. (2020). Developing Knowledge Tool Using Computer Aided Personal Interview Technique for Assessing the Climate Knowledge of Farmers of Odisha. *J. Community Mobilization Sustain. Dev*. *15* (3): 661-667.

Davis, F. D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Q. 13*(3): 319-340. https://doi.org/10.2307/249008

De Silva, H., and Ratnadiwakara, D. (2008). Using ICT to reduce transaction costs in agriculture through better communication: A case-study from Sri Lanka. *LIRNEasia, Colombo, Sri Lanka.*

Delone, W., and McLean, E. (2003). The DeLone and McLean Model of Information Systems Success: A Ten-Year Update. *J. Manag. Inf. Syst.*, *19*, 9–30. https://doi.org/10.1080/07421222.2003.11045748

Dewey, D. R., and Lu, K. H. (1959). A Correlation and Path-Coefficient Analysis of Components of Crested Wheatgrass Seed Production1. *J. Agron.*, *51*(9), 515–518. https://doi.org/10.2134/agronj1959.00021962005100090002x

Draper, N. R., and Smith, H. (1981). *Applied Regression Analysis*. Wiley, New Jersey, USA. pp. 75-99.

Ezekiel, M., and Fox, K. A. (1959). *Methods of Correlation and Regression Analysis, Linear and Curvilinear*. Wiley, New Jersey, USA.

Farmis, (2021), *Agrobase—Weed, disease, insect* (version1.2.4) [Mobile app] [Accessed 26 Dec.2021].https://play.google.com/store/apps/details?id=lt.farmis.apps.farmiscatalogandhl=en_USandgl=US

Food and Agriculture Organization of the United Nations (2021) *News Article: New standards to curb the global spread of plant pests and diseases*. Retrieved December 21, 2021, from https://www.fao.org/news/story/en/item/1187738/icode/

Ferentinos, K. P. (2018). Deep learning models for plant disease detection and diagnosis. *Comput. Electron. Agric.*, *145*, 311–318.

Food and Agriculture Organization of the United Nations (Ed.). (2017). *The future of food and agriculture: Trends and challenges*. Retrieved December 21, 2021, from https://www.fao.org/publications/fofa/en/FAO. The future of food and agriculture – Trends and challenges. Rome, Italy.

General Economic Division. (2020). *Bangladesh Eighth Five Year Plan (July 2020-June 2025), Promoting Prosperity and Fostering Inclusiveness.* Ministry of Planning, The Government of the People's Republic of Bangladesh, p. 305

George, D., and Mallery, P. (2006). *SPSS for Windows Step-by-Step: A Simple Guide and Reference, 14.0 update* (7th edition). Allyn and Bacon, Boston, USA.

Ghana, C. S, S., Singh, S., and Poddar, P."Deep Learning Model for Image-Based Plant Diseases Detection on Edge Devices," *6th Int. Conf. Conv. Tech. (I2CT)*, 2021, pp. 1-5, doi: 10.1109/I2CT51068.2021.9418124.

Guo, Y., Zhang, J., Yin, C., Hu, X., Zou, Y., Xue, Z., and Wang, W. (2020). Plant disease identification based on deep learning algorithm in smart farming. *Discrete Dyn. Nat. Soc.*, *2020*. https://doi.org/10.1155/2020/2479172

Hasan, M. F., Sayem, M., Sarmin, S., and Shahin, A. (2020). Effectiveness and Constraints of ICT Enablers Used by the Farmers in Northern Bangladesh. *Bangladesh J. Extn. Edu: 31*(1 and 2):39-50 https://doi.org/10.13140/RG.2.2.22209.38244

Hasan, R. I., Yusuf, S. M., and Alzubaidi, L. (2020). Review of the State of the Art of Deep Learning for Plant Diseases: A Broad Analysis and Discussion. *Plants*, *9*(10): 1302. https://doi.org/10.3390/plants9101302

Hasanuzzaman, M. (Ed.). (2019). Agronomic Crops: Management Practices. *Volume 2*. Springer, Singapore.

Hassan, M. S., Hassan, M. A., Samah, B. A., Ismail, N., and Shaffril, H. A. M. (2008). Use of information and communication technology (ICT) among agri-based entrepreneurs in Malaysia. Proc. World Conf. Agril. Inf. IT, Tokyo, Japan, 24-27 August. pp.753–762.

Heeks, R., and Alemayehu, M. (2009). Impact assessment of ICT-for-development projects: A compendium of approaches. Development Informatics Working Paper, *36*.

Herlina, M., Saefuddin, A., and Nurhadryani, Y. (2013). Structural Equation Modeling in Determining Factors That Influence User Satisfaction of Krs Online Ipb. *Xplore: J. Stat*, *1*(2). https://doi.org/10.29244/xplore.v1i2.12416

Islam, M., Dinh, A., Wahid, K., and Bhowmik, P. (2017). Detection of potato diseases using image segmentation and multiclass support vector machine. IEEE 30th Canadian Conf. Electric. Comp. Eng. (CCECE). 30 April-3 May, 2017 in Windsor, ON, Canada, pp. 1–4.

ItCraft. (2019). *Mobile and Web App Development Company* [Web site] [Accessed 01 Dec. 2021]https://itcraftapps.com/blog/10-awesome-tips-to-developing-user-friendlyapps/

Johari, J., Sahari, J., Wahab, D. A., Abdullah, S., Abdullah, S., Omar, M. Z., and Muhamad, N. (2011). Difficulty Index of Examinations and Their Relation to the Achievement of Programme Outcomes. *Procedia Soci. Behav. Sci. 18*. pp. 71–80. https://doi.org/10.1016/j.sbspro.2011.05.011

Kante, M., Oboko, R., and Chepken, C. (2017). Influence of Perception and Quality of ICT-Based Agricultural Input Information on Use of ICTs by Farmers in Developing Countries: Case of Sikasso in Mali. *Electron J. Inf. Syst. Dev. Count.*, *83*(1), 1–21. https://doi.org/10.1002/j.1681-4835.2017.tb00617.x

Karim, M. R., Meem, M., Rahman, S., Noman, R., and Huda, S. (2020). Use and Role of Mobile Phone for Information Services in Agricultural Activities. *Asian J. Agric. Ext., Economics Sociol. 38*(2): 102-110.

Kaur, R., and Kang, S. S. (2015). An enhancement in classifier support vector machine to improve plant disease detection. IEEE 3rd Int. Conf. MOOCs, Innov. Technol. Educ. MITE, 1-2 October, 2015, Amritsar, Punjab, India:135–140.

Kerlinger, F. N., and Lee, H. B. (1999). Foundations of Behavioral Research (4th edition). Wadsworth Publishing. Belmont, CA, USA.

Khalak, A., Sarker, M. A., and Uddin, M. N. (2018). Farmers' access to ICT based media in receiving farm information: A grassroots level study from Bangladesh. *American J. Rural Dev.*, *6*(1):14–20.

Khan, M. S., Rahman, M. H., and Uddin, M. N. (2017). Effectiveness of Agricultural Information and Communication Center in Technology Transfer to the Farmers in Bangladesh. *Asian J. Agril Ext., Economics Sociol.* pp. 1–11. https://doi.org/10.9734/AJAEES/2017/34998

Khan, R. U., Khan, K., Albattah, W., and Qamar, A. M. (2021). Image-Based Detection of Plant Diseases: From Classical Machine Learning to Deep Learning Journey. *Wirel. Commun. Mob. Comput.* https://doi.org/10.1155/2021/5541859

Khirade, S. D., and Patil, A. B. (2015). Plant disease detection using image processing. *Int. Conf. Comput. Commun. Control Autom. ICCUBEA 2015*: 26-30 February, 2015, Pune, India. 768–771.

Kirill Sidorov (2021) *Plant diseases* (version 80.91.30) [Mobile app] [Accessed 26 Dec. 2021].https://play.google.com/store/apps/details?id=com.do_apps.catalog_329andhl =en_USandgl=US

Kim, B. (2012). The diffusion of mobile data services and applications: Exploring the role of habit and its antecedents. *Telecom. Policy*, *36*(1), 69–81. https://doi.org/10.1016/j.tel pol.2011.11.011

Kothari, J. D. (2018). Plant Disease Identification using Artificial Intelligence: Machine Learning Approach. *Int. J. Innov. Res. Comp. Comm. Eng.*, *7*(11):11082–11085.

Kotler, P. (2000). Marketing Management (The Millennium Edition). Pearson College Div, New York, USA.

Lazer, D., Hargittai, E., Freelon, D., Gonzalez-Bailon, S., Munger, K., Ognyanova, K., and Radford, J. (2021). Meaningful measures of human society in the twenty-first century. *Nature*, *595*(7866):189–196. https://doi.org/10.1038/s41586-021-03660-7

Li, J., Jia, J., and Xu, D. (2018). Unsupervised representation learning of image-based plant disease with deep convolutional generative adversarial networks. *37th Chinese Contr. Conf. (CCC)*, 9159–9163.

Lin, K., Gong, L., Huang, Y., Liu, C., and Pan, J. (2019). Deep Learning-Based Segmentation and Quantification of Cucumber Powdery Mildew Using Convolutional Neural Network. *Front. Plant Sci.*, *10*: 155. https://doi.org/10.3389/fpls.2019.00155

Liu, B., Zhang, Y., He, D., and Li, Y. (2018). Identification of apple leaf diseases based on deep convolutional neural networks. *Symmetry*, *10*(1), p. 11.

Lowe, A., Harrison, N., and French, A. P. (2017). Hyperspectral image analysis techniques for the detection and classification of the early onset of plant disease and stress. *Plant Methods*, *13*(1), p. 80. https://doi.org/10.1186/s13007-017-0233-z

Anderson, L.W. and Bloom, B.S. and Krathwohl, D.R. and Airasian, P. and Cruikshank, K. and Mayer, R. and Pintrich, P. and Raths, J. and Wittrock, M. (2001). A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives. Longman, London, UK

Machado, B. B., Orue, J. P. M., Arruda, M. S., Santos, C. V., Sarath, D. S., Goncalves, W. N., Silva, G. G., Pistori, H., Roel, A. R., and Rodrigues-Jr, J. F. (2016). BioLeaf: A professional mobile application to measure foliar damage caused by insect herbivory. *Comp. Electron. Agric.*, *129*, 44–55. https://doi.org/10.1016/j.compag.2016.09.007

Malek, M.A. (2015a). Designing a Picture-based Agricultural Extension Tool Krishoker Janala (Farmer's Window) for Better Agricultural Advisory Service. *Bangladesh J.*

Extn. Edu., 27(1 and 2): 35-40.

Malek, M.A. (2015b). Impact of Using Pictorial Database Krishoker janala in providing Agricultural Advisory Services. *Bangladesh J. Extn. Edu., 27*(1 and 2): 93-101.

Mehta P. (1958). A study of communication of agricultural information and the extent of distribution occurring from district to village level workers in selected I.A.D.P. districts. Ph.D. dissertation. The University of Udaipur, Rajasthan, India.

Mendes, J., Pinho, T. M., Neves dos Santos, F., Sousa, J. J., Peres, E., Boaventura-Cunha, J., Cunha, M., and Morais, R. (2020). Smartphone Applications Targeting Precision Agriculture Practices—A Systematic Review. *Agron.*, *10*(6), 855.https://doi.org/10.3390/agronomy10060855

Mishra, S., Sachan, R., and Rajpal, D. (2020). Deep convolutional neural network based detection system for real-time corn plant disease recognition. *Procedia Comp. Sci.*, *167*: 2003–2010.

Mohanty, S. P., Hughes, D. P., and Salathé, M. (2016). Using Deep Learning for Image-Based Plant Disease Detection. *Front. Plant Sci.*, *7*, 1419. https://doi.org/10.3389/fpls.2016.01419

Mondal, M. H. (2010). Crop agriculture of Bangladesh: Challenges and opportunities. *Bangladesh J. Agric. Res.*, *35*(2):235–245.

Nagasubramanian, K., Jones, S., Singh, A. K., Sarkar, S., Singh, A., and Ganapathysubramanian, B. (2019). Plant disease identification using explainable 3D deep learning on hyperspectral images. *Plant Methods*, *15*(1), 98. https://doi.org/10.1186/s13007-019-0479-8

Pawar, P., Turkar, V., and Patil, P. (2016). Cucumber disease detection using artificial neural network. *Int. Conf. Inven. Technol (ICICT)*, *3*, 1–5. https://doi.org/10.1109/INVENTIVE.2016.7830151

Perry, N. C., and Michael, W. B. (1952). The Relationship of the Tetrachoric Correlation Coefficient to the Phi Coefficient Estimated from the Extreme Tails of a Normal Distribution of Criterion Scores. *Educ. Psychol. Meas.*, *12*(4): 778–786. https://doi.org/10.1177/001316445201200427

Peshin, R. (2013). Farmers' adoptability of integrated pest management of cotton revealed by a new methodology. *Agron. Sustain. Dev.*, *33*(3):563–572. https://doi.org/10.1007/s13593-012-0127-4

Petrellis, N. (2019). Plant Disease Diagnosis for Smart Phone Applications with Extensible Set of Diseases. *Applied Sciences*, *9*(9), 1952. https://doi.org/10.3390/app9091952

Plantix. (n.d.). *Plantix Best Agriculture App*. (version 3.6.6) [Mobile app] [Accessed 26 Dec. 2021]. https://plantix.net/en/

Prakash, R. M., Saraswathy, G. P., Ramalakshmi, G., Mangaleswari, K. H., and Kaviya, T. (2017). Detection of leaf diseases and classification using digital image processing. *Int. Conf. Inf. Commun. Embed. Syst. ICICES 2017*, 1–4.

Pydipati, R., Burks, T., and Lee, W. S. (2006). Identification of citrus disease using color texture features and discriminant analysis. *Comput. Electron. Agric.*, *52*. pp. 49–59. https://doi.org/10.1016/j.compag.2006.01.004

Quddus, A., and Kropp, J. D. (2020). Constraints to Agricultural Production and Marketing in the Lagging Regions of Bangladesh. *Sustainability*, *12*(10):39-56. https://doi.org/10.3390/su12103956

Ramesh, S., Hebbar, R., Niveditha, M., Pooja, R., Shashank, N., and Vinod, P. V. (2018). Plant disease detection using machine learning. *Int. Conf. Design Innov. 3Cs Compute Comm. Control (ICDI3C)*, 41–45.

Rashid, S. M. M., and Islam, M. R. (2016). Problems faced by farmers in application of e-Agriculture in Bangladesh. *J. Agric. Economics Rural Dev.*, *3*(1):79–84.

Rashid, S. M. M., Islam, M. R., and Quamruzzaman, Md. (2016). Which factor contribute most to empower farmers through e-Agriculture in Bangladesh? *SpringerPlus*, *5*(1):1742. https://doi.org/10.1186/s40064-016-3443-3

Reddy, S. R., Varma, G. S., and Davuluri, R. L. (2021). Optimized convolutional neural network model for plant species identification from leaf images using computer vision. *Int. J. Speech Technol*., *24*(8) pp. 1–28.

Roberts, S., and Spiezia, V. (2009). *Guide to measuring the information society, 2009.* Economic Analysis and Statistical Division, OECD. pp. 1–220.

Rogers, E. M. (1983). *Diffusion of Innovations*. Free Press. New York, USA. p. 15.

Rogers, E. M. (2003). *Diffusion of Innovations, 5th Edition* (5th edition). Free Press. New York, USA.

Rongbutsri, N., Rochanakit, K., Theppawong, S., Woraphat, P., Khantha, S., Kittakool, S., Kapanya, T., and Wicha, S. (2017). Mobile learning in museums: A case study of the Golden jubilee Museum of Agriculture Office. *Int. Conf. Digi. Arts, Media Technol.*, pp. 210–215. https://doi.org/10.1109/ICDAMT.2017.7904963

Roztocki, N., Soja, P., and Weistroffer, H. R. (2019). The role of information and communication technologies in socioeconomic development: Towards a multi-dimensional framework. *Inf.Technol. Dev. 25*(2):171–183.https://doi.org/10.1080/02681102.2019.1596654

Rupavatharam, S., and Kennepohl, A. (2018, August 3). Automated plant disease diagnosis using innovative android App (Plantix) for farmers in Indian state of Andhra Pradesh. Int. Congress Plant Pathologists, 29 July-3 August 2018, Sheraton Boston Hotel, Boston, USA.

Salam, A., and Khan, M. Z. (2020). Farmers' Perception Analysis about the Use of Information and Communication Technologies (ICT) in Agriculture Extension services of Khyber Pakhtunkhwa. *J. Soudi Agric. Sci.*, *18*(2). pp. 211-217. https://doi.org/10.17582/journal.sja/2020/36.3.754.760

Saleem, M. H., Khanchi, S., Potgieter, J., and Arif, K. M. (2020). Image-Based Plant Disease Identification by Deep Learning Meta-Architectures. *Plants*, *9*(11). p.1451. https://doi.org/10.3390/plants9111451

Sandino, J., Pegg, G., Gonzalez, F., and Smith, G. (2018). Aerial mapping of forests affected by pathogens using UAVs, hyperspectral sensors, and artificial intelligence. *Sensors*, *18*(4):944.

Sanga, C., Mlozi, M., Haug, R., and Tumbo, S. (2016). Mobile learning bridging the gap in agricultural extension service delivery: Experiences from Sokoine University of Agriculture, Tanzania. *Int. J. Educ. Dev. Using ICT*, *12*(3).

Spacenus (2021) Precision Farming and Agronomic Advisory. Retrieved Dec. 22, 2021, from https://www.spacenus.com

Sibiya, M., and Sumbwanyambe, M. (2019). A computational procedure for the recognition and classification of maize leaf diseases out of healthy leaves using convolutional neural networks. *Agri. Eng.*, *1*(1):119–131.

Statista (2021). *Global mobile app downloads 2023*. Retrieved December 20, 2021, from https://www.statista.com/statistics/241587/number-of-free-mobile-app-downloads worldwide/

Sultana, M., Ali, M., Islam, M., Kabir, M., and Hasnat, M. (2019). Effectiveness of Krisoker Janala in Disseminating Agricultural Information: An Innovative Tool. *Open J. Soc. Sci.*, *07*. pp. 272–280. https://doi.org/10.4236/jss.2019.73023

Tan, D. S., Leong, R. N., Laguna, A. F., Ngo, C. A., Lao, A., Amalin, D. M., and Alvindia, D. G. (2018). AuToDiDAC: Automated tool for disease detection and assessment for cacao black pod rot. *Crop Prot.*, *103* pp. 98–102.

Tata, J. S., and McNamara, P. (2018). Impact of ICT on agricultural extension services delivery:Evidence from the Catholic Relief Services SMART skills and Farm book project in Kenya. *J. Agric. Educ. Ext.*, *24*(3). pp. 1-22 https://doi.org/10.1080/1389224X.2017.1387160

Tavakol, M., and Dennick, R. (2011). Making sense of Cronbach's alpha. *Int. J. Med. Educ.*, *2* pp. 53–55. https://doi.org/10.5116/ijme.4dfb.8dfd

Tetila, E. C., Machado, B. B., Menezes, G. K., Da Silva Oliveira, A., Alvarez, M., Amorim, W. P., De Souza Belete, N. A., Da Silva, G. G., and Pistori, H. (2020). Automatic Recognition of Soybean Leaf Diseases Using UAV Images and Deep Convolutional Neural Networks. *IEEE Geosci.*. *17*(5). pp. 903–907. https://doi.org/10.1109/LGRS.

2019.2932385

Teegavarapu, S., J.D Summers, G.M. Mocko. 2008. Case Study Method for Design Research: A Justification. Proc. ASME Des. Eng. Tech. Conf., 3-6 August, American Society of Mechanical Engineers, Brooklyn, New York, USA.

Thar, S. P., Ramilan, T., Farquharson, R. J., Pang, A., and Chen, D. (2021). An empirical analysis of the use of agricultural mobile applications among smallholder farmers in Myanmar. *Electron. J. Inf. Syst. Dev. Ctries*., *87*(2), e12159. https://doi.org/10.1002/isd2.12159

Together, N.-L. G. Y. B. (2019, March 20). How to Measure the Effectiveness of a Mobile Application?*TheStartup*. https://medium.com/swlh/how-to-measure-the-effectiveness-of-a-mobile-application-23c29c6722cd

Townsend, D. N., and UNCTAD. (2011). Measuring the impacts of information and communication technology for development. https://digitallibrary.un.org/record/706731

Townsend, J. C. (1953). Introduction to Experimental Method (Internaltional Student Edition). McGraw Hill, Inc, New York, USA.

Upvision (2021). *BioLeaf - Foliar Analysis* (version 3.0) [Mobile app] [Accessed 26 Dec. 2021].https://play.google.com/store/apps/details?id=upvision.bioleafandhl=en_USandgl=US

Venkatesh, V., and Davis, F. (2007). A Model of the Antecedents of Perceived Ease of Use: Development and Test. *Decis. Sci.*, *27*. pp. 451–481. https://doi.org/10.1111/j.1540-5915.1996.tb00860.x

Venkatesh, V., Morris, M., Davis, G., and Davis, F. (2003). User Acceptance of Information Technology: Toward a Unified View. *MIS Quarterly*, *27* pp. 425–478. https://doi.org/10.2307/30036540

Vetal, S., and Khule, R. S. (2017). Tomato plant disease detection using image processing. *Int. J. Adv. Res. Comput. Commun. Eng.*, *6*(6), pp. 293–297.

Vishnoi, V. K., Kumar, K., and Kumar, B. (2020). Plant disease detection using computational intelligence and image processing. *J. Plant Dis. Prot.*, *128*. pp. 1–35.

Walle, T., Mekbib, F., Amsalu, B., and Gedil, M. (2018). Correlation and Path Coefficient Analyses of Cowpea (Vigna unguiculata L.) Landraces in Ethiopia. *American J. Plant Sci.*, *9*(13). pp. 2794–2812. https://doi.org/10.4236/ajps.2018.913202

Wallelign, S., Polceanu, M., and Buche, C. (2018). Soybean plant disease identification using convolutional neural network. *Proc, 31st Int. Fla. Artif. Intell. Res. Soc. Conf. FLAIRS*. May 21, Melbourne, USA. pp. 146-151.

Water J.(2021). *Imscope* (version1.2.4) [Mobile app] [Accessed 26 Dec.2021]. https://play.

google.com/store/apps/details?id=com.idoneos.imscopeandhl=en_USandgl=US

IBM. (2021.).What is Computer Vision*?* Retrieved December 26, 2021, from https://www.ibm.com/in-en/topics/computer-vision

Wilson, R. S. I., Goonetillake, J. S., Ginige, A., and Indika, W. A. (2021). Analysis of information quality for a usable information system in agriculture domain: A study in the Sri Lankan context. *Procedia Comput. Sci*., *184*. pp. 346–355. https://doi.org/10.1016/j.procs.2021.03.044

Yang, X., and Guo, T. (2017). Machine learning in plant disease research. *European J.Bio Medl. Res. 3* (1). pp. 6-9.

Yin, R.K. 2003. Case study research: Design and Methods, Sage Publications, California, USA. pp. 19-53.

Zhang, X., Murad, A., Risher, A., and Simmons, J. (2016). How to Measure IT Effectiveness: The CIO's Perspective. SAIS 2016 Proceedings. https://aisel.aisnet.org/sais2016/22

Zhou, R., Kaneko, S., Tanaka, F., Kayamori, M., and Shimizu, M. (2013). Early detection and continuous quantization of plant disease using template matching and support vector machine algorithms. 1st Int. Symp. Comput. Netw., 3-6 December, Matsuana, Japan. pp. 300–304.

Zygomatic. (2021). *Free online word cloud generator and tag cloud creator*. Wordclouds.Com. Retrieved December 31, 2021, from https://classic.wordclouds.com/

Appendices

Appendix I

English version of the Interview schedule

Department of Agricultural Extension and Information System

Sher-e-Bangla Agricultural University, Dhaka – 1207

Interview schedule for conducting research on

"EFFECTIVENESS OF IMAGE-BASED PLANT DISEASE DETECTION SYSTEM (IPDDS)"

Sample No. Mobile phone #

Name of the respondent: Gender:

Profession: ……………………………Use Purpose: ………………….

Address:

Village…………………………………Union………………………………….…

Thana………………………District………………………Region……………...

(Please provide following information. Your information will be kept confidential and will be used for research purpose only.)

1. Age

How old are you? ………………………… years.

2. Education

Please put tick mark (√) in the appropriate parenthesis or mention your level of education.

i) Can't read and write. ( )
ii) Can't read and write but can sign only. ( )
iii) I learnt reading and writing from adult learning center. ( )
iv) I read up to class ………………………………… ( )

3. Use of ICT (ICT device and internet)

Please mention your extent of use of ICT by putting tick mark (√) in the appropriate column.

Sl. No.	Items	Maximum score for use of ICT			
		Regular	Occasional	Rare	Not at all
1	Mobile device - offline	3	2	1	0
2	Mobile device - online	4	3	2	0

3	Computer device - offline	5	4	3	0
4	Computer device - online	6	5	4	0
5	Computer and Mobile device - offline	7	6	5	0
6	Computer and Mobile device - online	8	7	6	0

4. Farming experience

Please mention your farming experience in years. ……………years.

5. Crop farm size

Please mention about the size of your crop farm size on the following items:

Sl. no.	Items	Crop farm size	
		Local unit	Decimal
1	Own land under own cultivation		
2	Land taken from others as lease or share basis		
Total			

6. Annual crop production income

Please provide information about your current year crop production income.

Sl. no.	Crops	Production (Kg)	Price/Kg (BDT)	Total income ('000'BDT)
A) Cereal crops				
1	Rice			
2	Wheat			
3	Maize			
B) Vegetable crops				
1	Brinjal			
2	Potato			
3	Tomato			
4	Bean			
6	Cabbage			
C) Fruit Crops				
1	Mango			
2	Banana			
3	Jackfruit			
4	Papaya			
D) Other crops (Please mention)				
Total income				

7. Time saved

a) How much delay occurred in getting disease-related service without using IPDDS?…………hours.

b) How much delay occurred in getting disease-related service using IPDDS?................hours. Time saved = a-b =………hours.

8. Cost saved

a) How much cost needed in getting disease-related service without using IPDDS?...............TK.

b) How much cost needed in getting disease-related service using IPDDS? …….TK.
Cost saved = a-b =………TK.

9. Visit saved

a) How much visit needed in getting disease-related service without using IPDDS?........

b) How much visit needed in getting disease-related service using IPDDS? …….
Visit saved = a-b =……….

10. Individual Extension contact

Please give the information about your extent of contact with the following individual media by putting tick (√) in the appropriate column.

Sl. no.	**Extension media**	**Extent of individual extension contact**			
		Regular (3)	**Occasional (2)**	**Rare (1)**	**Not at all (0)**
Personal communication exposure					
1	Neighbor/relative farmers	>6 times /month	4-6 times /month	1-3 times /month	No contact
3	Model/leader Farmers	>4 times /month	3-4 times /month	1-2 times /month	No contact
4	Agricultural input dealers (seed, Fertilizer, Pesticides etc)	>3 times /month	2-3times / month	1 time / month	No contact
	Block/Union level Extension agents (GO/NGO)	>2 times /month	2 times /month	1 times /month	No contact
5	Upazilla or above level extension service providers	>4 times /quarter	3-4 times /quarter	1-2 times /quarter	No contact

11. Knowledge on plant disease management

Please answer the following questions by putting tick (√) mark.

Item no.	**Items of plant disease management knowledge test**
Remembering	
1	Which one of the following is a dangerous disease for rice? □BPH □ Blast □ Rice Hispa
2	Which one is an IPDDS? □ Plantix □ Krishoker Janala □ Both
Understanding	

Item no.	Items of plant disease management knowledge test
3	Why do you use IPDDS? □ It saves time. □ To get service timely □ Both of two
4	What will you do to produce safe food? □ Using non chemical approach □ Applying IPM □ Both □ None
Applying	
5	How do you use IPDDS? □ By installing in smartphone □ Sharing from service provider □ Both
6	How do you produce safe crop? □ By using IPM □ By using chemicals □ Both
Analyzing	
7	Why farmers show low interest to use IPDDS? □ Need smartphone □ Need literacy □ Both of the two
8	Why quality smartphone is needed to use IPDDS? □ To capture quality image □ To look good □ None
Evaluating	
9	What is the disadvantages of keeping crop field infested? □ Production decrease □ Quality of produce decrease □ Both
10	What is the benefit of seed treatment? □ Reduce seed borne disease □ Produce healthy seedling □ Both
Creating	
11	How to identify unknown disease of plant when IPDDS can't identify it? □ By using IPDDS image library □ Asking local leader □ Burning crop
12	In case of un-availability of internet, what will you do? □ Use of off-line IPDD system □ Use common sense □ None

12. Use of IPDDS

Please mention the degree of your use of following IPDDSs for detecting plant diseases by putting tick (√) in the appropriate column.

Name of IPDDS	Extent of Use			
	Regular use	Occasional use	Seldom use	Not at all use
Krishoker janala				
Plantix				
Plant Doctor				
Total				

13. Benefits of using IPDDS

Please mention the extent of benetits of IPDDS as perceived by you by putting tick mark (√) in the appropriate column.

Sl. no.	Items	Extent of benefits			
		High benefit (3)	Modera te benefit (2)	Low benefit (1)	Not at all benefit (0)
1	Reduce time for detecting disease				

2	Reduce disease detecting cost				
3	Increase production				
4	Increase service accessibility				
5	Increase service quality				
6	Reduce pesticide use				
7	Increase net income				
8	Increase farmers' knowledge				
9	Increase quality of produces				
Total					

14. Obstacles faced in using IPDDS

Please indicate the extent of obstacles faced by you in using IPDDS by putting tick mark (√) in the appropriate column and give your suggestions to mitigate the obstacles.

Sl. no.	**Items of obstacle**	**Extent of problem faced**				**Suggestions to mitigate the obstacles**
		Severe obstacle (3)	**Moderate obstacle (2)**	**Less obstacle (1)**	**No obstacle (0)**	
A. Socio-economic problems						
1	Illiteracy					
2	Unavailability of smart phone					
B. Technical problems						
3	Lack of sufficient internet speed					
4	Need technical knowledge to use IPDDS					
5	Inadequate extension service to support use of IPDDS					
6	Disease detection at early stage					
7	Presence of multiple diseases in a same plant					
8	Presence of background of the image					
E. Psychological problems						
9	Apathy to use IPDDS					
10	ICT phobia					
	Total					

15. Effectiveness of Image-based Plant Disease Detection System (IPDDS)

Please mention the degree of effectiveness of IPDDS as perceived by you.

Sl. no.	**Items of effects**	**Extent of effects**			
		Highly effective (3)	**Moderately effective (2)**	**Less effective (1)**	**Not at all effective (0)**

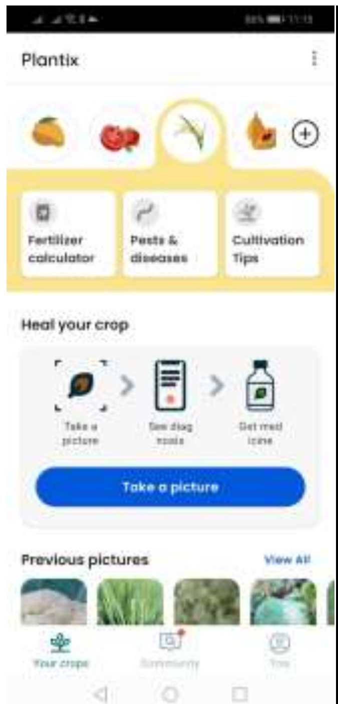
A. System accuracy					
1	Proper identification of plant disease				
2	Smooth working system				
3	Negligible error in the system				
B. User-friendliness					
4	Easy to use				
5	Easy to remember how to use				
6	Lower size of the software				
7	Lower device hanging tendency				
8	Comfort to use				
C. Off-line usability					
9	Off-line running				
10	Off-line installation				
11	Off-line sharing				
D. Device responsiveness					
12	Running in any smart device				
13	Requirement of lower processor				
14	Platform operability				
E. Content quality					
15	Usefulness of content				
16	Updated content				
17	Validity of content				
F. User satisfaction					
18	Ease of the system				
19	Delivery of the service				
20	Service cost				
21	On-time service				
22	Time needed for getting service				
Total					

Thank you for your cooperation.

…………………………………………..
Signature of the Interviewer with date

Appendix II

Snapshots of Mobile Applications of some IPDDS



APPENDIX III

Pre-test Items of Knowledge on plant disease management Test

Item No.	Items of Knowledge on plant disease management Test
Remembering	
1.a	Which of the following is harmful insect? □ Lady bird beetle □ Fruit and shoot borer □ Praying mantid
1.b	Which one is an IPDDS? □ Plantix □ Krishoker Janala □ Both
1.c	Which of the following is the best control measure for rice bug? □ Burning tire □ Oil cake □ Cowdung
1.d	Which one of the following is a dangerous disease for rice? □BPH □ Blast □ Rice Hispa
Understanding	
2.a	Why do you use IPDDS? □ It saves time. □ To get service timely □ Both of two
2.b	Which is the cause for increasing plant disease infestation? □ Use of chemical fertilizer and pesticides in the crop field □ Use of infected seed □ Both of the above
2.c	What will you do to produce safe food? □ Using non chemical approach □ Applying IPM □ Both □ None
2.d	How can you produce environment-friendly agricultural crops? □ By using chemical fertilizer and pesticides in the crop field □ By using organic manure and botanical pesticides in the crop field □ Don't know
Applying	
3.a	How insects can be controlled by light trap? □ By killing flying insects accumulated in the light trap □ All types of insects can accumulate in the light trap, then these should be killed □ No insect can be controlled by light trap
3.b	How do you use IPDDS? □ By installing in smartphone □ Sharing from service provider □ Both
3.c	How do you produce safe crop? □ By using IPM □ By using chemicals □ Both
3.d	How bio-pesticides are used? □ By spraying □ By mixing with seeds □ None of the above
Analyzing	

4.a	Why farmers show low interest to use IPDDS? □ Need smartphone □ Need literacy □ Both of the two
4.b	Why quality smartphone is needed to use IPDDS? □ To capture quality image □ To look good □ None
4.c	It is becoming hard to control pest even after use of high doses of chemical pesticides, why? □ Pests are becoming resistant to chemical pesticides □ Impure pesticides □ Both of the above
4.d	How beneficial insects can help in agriculture? □ By eating harmful insects □ Help in pollination □ Both of the above
Evaluating	
5.a	What is the disadvantages of keeping crop field infested? □ Production decrease □ Quality of produce decrease □ Both
5.b	What is the demerit of using chemical pesticide in the crop field? □ Create toxicity in the soil □ Decrease soil microbial activity □ Both of the above
5.c	What is the benefit of seed treatment? □ Reduce seed borne disease □ Produce healthy seedling □ Both
5.d	What is the demerit of decreasing of trees and plants? □ Create environmental pollution □ Decrease crop productivity □ Both of the two
Creating	
6.a	How to identify unknown disease of plant when IPDDS can't identify it? □ By using IPDDS image library □ Asking local leader □ Burning crop
6.b	How can you control aphid from bean field? □ By applying ash on the bean plant □ By putting bamboo in the field □ By putting tree branches in the field
6.c	In case of un-availability of internet, what will you do? □ Use of off-line IPDD system □ Use common sense □ None
6.d	What do you do with the crop residues and weeds? □ It is mixed in the soil as fertilizers □ It is thrown to other places without any use □ It is used as fuel

APPENDIX IV

Difficulty Indices and Discrimination Indices of the 36 Items of Knowledge on plant disease management Test

Sl.No. of Items	Frequencies of correct answers given by each group of respondents (each group containing 4 users)						Total frequencies of (N=24)		Difficulty index (P)	Discrimination Index ($E^{1/3}$)
	G_1	G_2	G_3	G_4	G_5	G_6	correct answers	Wrong answers		
1.a	0	1	0	1	1	0	3	21	12.50	0
1.b	4	4	3	3	3	3	20	4	83.33*	0.25*
1.c	1	0	0	1	0	1	3	21	12.50	0
1.d	4	4	2	2	3	2	17	7	70.83*	0.375*
2.a	4	4	4	4	2	2	20	4	83.33*	0.5*
2.b	3	4	4	4	4	3	22	2	91.67	0
2.c	2	1	0	0	1	0	4	20	16.67*	0.25*
2.d	1	0	1	0	0	1	3	21	12.50	0
3.a	0	1	0	0	0	1	2	22	8.33	0
3.b	3	3	4	4	1	0	15	9	62.50*	0.625*
3.c	4	4	3	3	3	3	20	4	83.33*	0.25*
3.d	2	0	0	0	1	0	3	21	12.50	0.125
4.a	2	4	4	4	3	2	19	5	79.17*	0.125*
4.b	3	2	4	4	2	1	16	8	66.67*	0.25*
4.c	4	4	4	3	4	3	22	2	91.67	0.125
4.d	4	4	3	2	0	0	13	11	54.17	1
5.a	4	3	3	3	1	0	14	10	58.33*	0.75*
5.b	0	1	2	1	1	0	5	19	20.83	0
5.c	3	3	3	2	1	1	13	11	54.17*	0.5*
5.d	4	4	4	3	0	0	15	9	62.50	1
6.a	4	4	2	2	4	3	19	5	79.17*	0.125*
6.b	4	4	4	4	4	3	23	1	95.83	0.125
6.c	3	3	1	1	0	0	8	16	33.33*	0.75*
6.d	3	2	3	2	3	2	15	9	62.50	0

* Items selected for the study

Appendix V

The t-values of the items of effectiveness of IPDDS

	Sl. No.	Items of Effectiveness	t-value
System accuracy	1	Proper identification of plant diseases	2.24*
	2	Smoothly working system	2.24*
	3	Speedy system	1.53
	4	Installation easy	1.17
	5	Negligible error in the system	2.24*
User-friendliness	6	Easy instruction	1.46
	7	Easy to use	2.24*
	8	Easy to remember how to use	2.24*
	9	Easy to remove from device	1.20
	10	Lower size of the software	2.24*
	11	Lower device hanging tendency	1.86*
	12	Comfort to use	2.24*
	13	Comfort to eye	0.54
	14	Low skill needed	1.54
	15	No buffering	1.46
Off-line usability	16	Off-line running	2.24*
	17	Off-line installation	2.24*
	18	Off-line uploading	1.53
	19	Off-line sharing	1.91*
Device responsiveness	20	Running in any smart device	2.24*
	21	Requirement of lower processor	2.00*
	22	Platform operability	2.24*
Content quality	23	Usefulness of content	2.24*
	24	Updated content	2.24*
	25	Validity of content	2.54*
	26	Easy language	1.00

User satisfaction	27	Ease of the system	2.24*
	28	Delivery of the service	2.24*
	29	Service cost	2.24*
	30	On-time service	2.00*
	31	Time needed for getting service	2.08*
	32	Low waiting time	1.41

*Significant t-value and finally selected for the scale

Appendix VI
Correlation Matrix

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	Y
X_1	-														
X_2	.257**	-													
X_3	.144**	.322**	-												
X_4	.203**	.001	-.010	-											
X_5	.024	-.032	-.081	.147**	-										
X_6	-.028	-.078	-.059	.161**	.741**	-									
X_7	.025	.013	.037	.060	.095	.049	-								
X_8	.067	-.042	.066	.055	.050	.053	.496**	-							
X_9	.078	.022	-.036	.122*	.106*	.069	.720**	.457**	-						
X_{10}	.154**	.000	-.048	.206**	.288**	.296**	.137**	.056	.147**	-					
X_{11}	.111*	.194**	.186**	.114*	.031	.048	.176**	.121*	.099	.255**	-				
X_{12}	.047	.149**	.215**	.084	.052	.103*	.172**	.173**	.113*	.236**	.338**	-			
X_{13}	-.077	-.010	-.006	.084	.088	.080	.124*	.006	.038	.162**	.035	.132**	-		
X_{14}	-.103*	-.015	-.083	-.002	.199**	.135**	.025	-.043	-.010	.158**	-.158**	-.025	.299**	-	
Y	.029	-.023	.134**	.029	.064	.088	.376**	.192**	.153**	.142**	.295**	.202**	.188**	-.104*	-

X_1= Age
X_2= Education
X_3= Use of ICT
X_4= Farming experience
X_5= Crop farm size
X_6= Annual crop production income
X_7= Time saved
X_8= Cost saved
X_9= Visit saved
X_{10}= Individual extension contact
X_{11}= Knowledge on plant disease management
X_{12}= Use of IPDDS
X_{13}= Benefits of using IPDDS
X_{14}= Obstacles in using IPDDS
Y=Effectiveness of using IPDDS

Appendix VII
Step-wise Multiple Regression

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	Time saved	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	Knowlwdge on plant disease managemant	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
3	Benefit of using IPDDS	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
4	Obstacles in using IPDDS	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
5	Use of ICT use	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
a. Dependent Variable: Effectiveness of using IPDDS			

Model Summary[f]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.485[a]	.235	.233	8.074
2	.548[b]	.300	.297	7.734
3	.578[c]	.334	.329	7.554
4	.588[d]	.346	.339	7.498
5	.594[e]	.353	.345	7.465
a. Predictors: (Constant), Time saved				
b. Predictors: (Constant), Time saved, Knowlwdge on plant disease managemant				
c. Predictors: (Constant), Time saved, Knowlwdge on plant disease managemant, Benefit of using IPDDS				
d. Predictors: (Constant), Time saved, Knowlwdge on plant disease managemant, Benefit of using IPDDS, Obstacles in using IPDDS				
e. Predictors: (Constant), Time saved, Knowlwdge on plant disease managemant, Benefit of using IPDDS, Obstacles in using IPDDS, Use of ICT use				
f. Dependent Variable: Effectiveness of using IPDDS				

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	7660.857	1	7660.857	117.520	.000[b]
	Residual	24901.799	382	65.188		
	Total	32562.656	383			
2	Regression	9775.497	2	4887.748	81.723	.000[c]
	Residual	22787.160	381	59.809		
	Total	32562.656	383			
3	Regression	10876.009	3	3625.336	63.524	.000[d]
	Residual	21686.647	380	57.070		
	Total	32562.656	383			
4	Regression	11257.174	4	2814.294	50.063	.000[e]
	Residual	21305.482	379	56.215		
	Total	32562.656	383			
5	Regression	11497.735	5	2299.547	41.264	.000[f]
	Residual	21064.922	378	55.727		
	Total	32562.656	383			

a. Dependent Variable: Effectiveness of using IPDDS

b. Predictors: (Constant), Time saved

c. Predictors: (Constant), Time saved, Knowlwdge on plant disease managemant

d. Predictors: (Constant), Time saved, Knowlwdge on plant disease managemant, Benefit of using IPDDS

e. Predictors: (Constant), Time saved, Knowlwdge on plant disease managemant, Benefit of using IPDDS, Obstacles in using IPDDS

f. Predictors: (Constant), Time saved, Knowlwdge on plant disease managemant, Benefit of using IPDDS, Obstacles in using IPDDS, Use of ICT use

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	31.584	.785		40.231	.000
	Time saved	.909	.084	.485	10.841	.000
2	(Constant)	19.426	2.179		8.917	.000
	Time saved	.818	.082	.437	10.005	.000
	Knowlwdge on plant disease managemant	1.403	.236	.259	5.946	.000
3	(Constant)	3.289	4.246		.775	.439
	Time saved	.779	.080	.415	9.688	.000

	Knowlwdge on plant disease managemant	1.317	.231	.243	5.693	.000
	Benefit of using IPDDS	.716	.163	.186	4.391	.000
4	(Constant)	4.843	4.257		1.138	.256
	Time saved	.784	.080	.419	9.829	.000
	Knowlwdge on plant disease managemant	1.219	.233	.226	5.245	.000
	Benefit of using IPDDS	.809	.166	.210	4.882	.000
	Obstacles in using IPDDS	-.299	.115	-.112	-2.604	.010
5	(Constant)	2.433	4.394		.554	.580
	Time saved	.782	.079	.417	9.843	.000
	Knowledge on plant disease management	1.127	.236	.208	4.781	.000
	Benefit of using IPDDS	.802	.165	.208	4.859	.000
	Obstacles in using IPDDS	-.285	.114	-.107	-2.488	.013
	Use of ICT use	.550	.265	.088	2.078	.038
a. Dependent Variable: Effectiveness of using IPDDS						

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	Use of use of IPDDS	.117[b]	2.579	.010	.131	.964
	Benefit of using IPDDS	.207[b]	4.702	.000	.234	.983
	Personal extension contact	.077[b]	1.718	.087	.088	.981
	Knowlwdge on plant disease managemant	.259[b]	5.946	.000	.291	.965
	Use of ICT use	.143[b]	3.235	.001	.163	.997
	Crop farm size	.050[b]	1.107	.269	.057	.986
	Visit saved	-.117[b]	-1.754	.080	-.090	.451
	Cost saved	.035[b]	.732	.465	.037	.864
	Obstacles in using IPDDS	-.101[b]	-2.268	.024	-.115	.999
2	Use of use of IPDDS	.036[c]	.774	.439	.040	.861
	Benefit of using IPDDS	.186[c]	4.391	.000	.220	.976
	Individual extension contact	.019[c]	.418	.676	.021	.928

	Use of ICT use	.096[c]	2.197	.029	.112	.957
	Crop farm size	.048[c]	1.123	.262	.057	.986
	Visit saved	-.111[c]	-1.737	.083	-.089	.451
	Cost saved	.040[c]	.861	.390	.044	.864
	Obstacles in using IPDDS	-.067[c]	-1.544	.123	-.079	.980
3	Use of use of IPDDS	.007[d]	.160	.873	.008	.843
	Individual extension contact	-.003[d]	-.059	.953	-.003	.917
	Use of ICT use	.094[d]	2.213	.028	.113	.957
	Crop farm size	.058[d]	1.378	.169	.071	.984
	Visit saved	-.088[d]	-1.408	.160	-.072	.447
	Cost saved	.036[d]	.793	.428	.041	.863
	Obstacles in using IPDDS	-.112[d]	-2.604	.010	-.133	.934
4	Use of use of IPDDS	.011[e]	.237	.812	.012	.842
	Individual extension contact	.020[e]	.455	.650	.023	.882
	Use of ICT use	.088[e]	2.078	.038	.106	.954
	Farm size	.070[e]	1.655	.099	.085	.974
	Visit saved	-.092[e]	-1.484	.139	-.076	.447
	Cost saved	.030[e]	.668	.505	.034	.861
5	Use of use of IPDDS	-.002[f]	-.037	.971	-.002	.828
	Individual extension contact	.030[f]	.668	.504	.034	.873
	Farm size	.069[f]	1.648	.100	.085	.974
	Visit saved	-.086[f]	-1.397	.163	-.072	.446
	Cost saved	.030[f]	.673	.501	.035	.861
a. Dependent Variable: Effectiveness of using IPDDS						
b. Predictors in the Model: (Constant), Time saved						
c. Predictors in the Model: (Constant), Time saved, Knowlwdge on plant disease managemant						
d. Predictors in the Model: (Constant), Time saved, Knowlwdge on plant disease managemant, Benefit of using IPDDS						
e. Predictors in the Model: (Constant), Time saved, Knowlwdge on plant disease managemant, Benefit of using IPDDS, Obstacles in using IPDDS						
f. Predictors in the Model: (Constant), Time saved, Knowlwdge on plant disease managemant, Benefit of using IPDDS, Obstacles in using IPDDS, Use of ICT use						

Appendix VIII

Published Article on the Case Study

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Image-Based Plant Disease Detection: an Experience of Bangladesh

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ABSTRACT

Use of image-based plant disease detection system (IPDDS) is getting popularity day by day. In this case images of plant diseases are used to detect the symptom. Several sophisticated techniques are used in IPDDS. But in the recent year Bangladesh has experienced a very simple solution called *krishoker janala* (farmer's window) in providing agricultural advisory services to the farmer. It is actually an image-based system (mobile application also available) of plant disease detection. Farmer/ user can easily real-time identify problem of their plant by matching the symptom of the plant with the image of the system. A case study was conducted to find out the effectiveness of *krishoker janala* as perceived by the user. The study reveals that 84.62%, 11.54% and 3.85% respondent found *kriskoker janala* as highly effective, moderately effective and less effective respectively. The study also found that 92% respondents could solve their plants' problem using *krishoker janala* application; did not need help from others. That was an exceptional experience of Bangladesh in the field of image-based plant disease detection. Study also reveals that user reported some problems regarding the mobile application and they also provided some recommendations to increase the effectiveness of the system. These recommendations to be considered for increasing the effectiveness of this system during next updating. Policy maker of the country should include IT-industry into collaboration to incorporate automate system

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Introduction

Agriculture covers the first two important goals of United Nation (UN) declared Sustainable Development Goals (SDGs) namely 'No poverty' and 'Zero hunger'. Bangladesh-an agrarian country is fighting to achieve SDGs. But the farmers of the country face several problems in growing crops like lack of proper agricultural inputs, labor crisis during peak seasons of planting and harvesting, low price of the produces, and infestation of pests and diseases etc. Although Bangladesh has got a very grass root level agricultural extension services, farmer often suffered from lack of information and advices during the infestation. To get necessary information and advice from Upazila Agriculture Office, farmers had to visit almost 5 to 30 Kilometers. Sometimes visiting the long distance to Upazila Agriculture Office, farmers failed to meet with Upazila Agriculture Officer or other service providers. When a farmer came to the agriculture office or to an agricultural extension service provider, sometimes he/she failed to come with a symptom of the disease or the farmer failed to explain the problem to the extension service provider clearly and thus it became difficult for the extension service provider to identify the disease. The service provider then had to make field visit to identify the problem and suggest requisite solution to overcome the problem (Malek, 2015). The process was costly in terms of both money and time. With the advances of computer vision technology, several image-based plant disease detection systems are under experiment and to some extent available (Rupavatharam *et al*, 2018).

Image-based Plant Disease Detection System (IPDDS)

Image-based plant disease detection system (IPDDS) can be defined as a system where plant images are used to detect plant disease. The use of computer vision, and object recognition has made tremendous advances in the past few years (Mohanty *et al.*, 2016). A wide range of technologies are used in IPDDS such as using support vector machine (Islam *et al*., 2017), image processing (Abramoff *et al*.,2004), using image classification technique (Revathi *et al*., 2013), image segmentation (Islam *et al*., 2017), using image library (Malek, 2015). Besides-back propagation technique, Artificial Neural Network (ANN), Convolutional Neural Network (CNN) are also very promising technologies for IPDDS. Among those techniques of IPDDS, using image library is very easy to build, operate and low-cost one (Malek, 2015). It is not very high-tech. Our study was on this type of IPDDS.

With availability of smart-phone, image-based plant disease detection is getting attention in a growing speed. Various applications have been developed. Some of the applications are being used at field level. But effectiveness of very few of them have been studied from farmers/ users point of view. Most of the studies were on the development and performance of the system. This study reviewed the works done so far for bringing the innovation into the context of rural farmers. Mohanty *et al*.(2016) developed a system to identify plant disease automatically. Using a public dataset of 54,306 images of diseased and healthy plant leaves, they found an accuracy of 99.35% on a held-out test set and they claim it as a demonstration of the feasibility of their approach. They collected the images under controlled conditions, they trained a deep convolutional neural network to identify 14 crop species and 26 diseases (or absence thereof). Rupavatharam *et al.(*2018) studied system of Progressive Environment Agriculture Technologies (PEAT), a German startup company developed mobile application ‘Plantix’ that assists in detecting damage on plants with the help of a smart phone image. They reported 90% accuracy of the system. Tan *et al*. (2018) introduces a mobile application named AuToDiDAC or Automated Tool for Disease Detection and Assessment for Cacao Black Pod Rot (BPR) that automatically detects, separates, and assesses the infection level of BPR in cacao through image processing and machine learning techniques. They reported an average of 84% accuracy on an independent test set of ten cacao pod images. Barbedo (2016) studied the problems associated with automatic plant disease identification using visible range images like presence of complex backgrounds in the images, undefined boundaries of the symptoms, uncontrolled image capture conditions that make the image analysis difficult, diseases producing symptoms with a wide range of characteristics, presence of multi symptoms etc.. He analyzed the problems and proposed possible solutions capable of overcoming at least some of those challenges. Ferentinos (2018) developed convolutional neural network models to perform plant disease detection and diagnosis using simple leaves images of healthy and diseased plants, through deep learning methodologies. He used an open database of 87,848 images, containing 25 different plants in a set of 58 distinct classes of [plant, disease] combinations, including healthy plants to train the models. He reported 99.53% success rate in identifying the corresponding [plant, disease] combination (or healthy plant) suggested the models as very useful advisory or early warning tool, and expandable to support an integrated plant disease identification system to operate in real cultivation conditions.

All the above mentioned initiatives were found to be very sophisticated. High-level technology had been used and a huge cost and resources involved. Implementation of the service needed to invest huge capital and resources. But these systems have got several challenges to identify crop diseases like image quality, image background, image taking condition etc. (Barbedo, 2016). Some of these challenges cause the system low effective in performance. Moreover, these systems need huge resources and fund for implementation. In these circumstances, the farmers of Bangladesh have experienced a new experience of an innovative solution called *krishoker janala*. Farmer having installed the mobile app, can easily match the problem of the crop with the pictures of the image library of the app. It is consisting of more than 1000 problems of about 120 crops. It is available both online and offline mode (Malek, 2015). The main objective of the study was to assess the effectiveness of the *krishoker janala* app for providing agricultural services to the farmers. Specific objectives of the study were as follows:

- To explore farmer’s understanding on *krishoker janala* mobile application
- To find out the benefits that farmers are getting through using the mobile application
- To identify the challenges faced by users while using the app
- To analyze *krishoker janala* as a service
- To measure the satisfaction level of the user farmer
- To find out improvement scope of the mobile application desired by the user.

Methodology

The study was conducted as a case study. Although case study research method is often considered to be invalid, invaluable and improper (Yin, 2003), it is an established research method in social sciences (Teegavarapu *et al.*, 2008) -a review of literature in social sciences (Yin, 2003; Lukoff *et al.*,1998 and Dresch *et al*., 2015) support the argument. The study was conducted in two upazilas viz. Sadar upazila of Norsindi and Sadar upazila of Gazipur. The upazilas were selected based on the user density report provided by Department of Agriculture Extension (DAE). Top two user density upazilas were selected for the study. Two Focus Group Discussions (FGDs) were conducted (10 participants each). Key Informant Interview was conducted with Upazila Agriculture Officer, Agriculture Extension Officer and Sub-Assistant Agriculture Officer to get primary data. Secondary documents, media reports etc. were thoroughly studied. The content of the website, application and user responses were also studied. Based on FGDs, Key Informant Interview and review of literature and secondary documents, interview schedule was prepared. Users of almost all categories were included in the study. Out of 3328 registered users a total of 330 users were selected randomly from *krishoker janala* app user registration information and interviewed. Reviews of the app user were also collected from Google play store. After completing the collection of data, data were cleaned and analyzed and graphs and charts were presented in excel.

Some limitations of the study included: firstly- interviewee from *krishoker janala* app users registration information, were those users who had registered themselves for sending picture to the application. (*krishoker janala* has got a picture sending option). Secondly-reviewers of the app are advanced level users. Ensuring proportionate sampling was a challenge of the study. To overcome the limitations and ensuring Guba's (Guba, 1981) criteria (credibility, transferability, dependability and confirmability) for the study; various techniques were applied such as consultation of appropriate documents and preliminary visits to the respondents and authority (Lincoln *et al*.,1981) were done and good relationship (Erlandson *et al*.,1993) was established between researcher and users. Triangulation (Maanen, 1983) was done by the use of a wide range of informants. The use of "overlapping methods" as suggested by Shenton *et al.* (2004) was done by conducting the FGDs and personal interview. Despite all these steps, the presence of advance user was dominating to some extent in this study. Therefore, scopes prevail for further study to know the opinion of common users of *kriskoker janala* mobile application. Regarding using case study as research methods it can be concluded with the help of Yin, the most prominent critic of this method that case study is not only a suitable method to explore the subject; it also can be used to explain certain phenomena (Yin, 1984).

Result and Discussion

Bangladesh's experience on Image-based Plant Disease Detection System (IPDDS)

From the study it was found that, considering the problems faced by Bangladeshi farmers in getting agricultural advisory services Malek (2015) designed an image-based plant's problem (pest and disease) identification system later get popularity as *krishoker janala*. He collected images of plants' problem from several parts of Bangladesh. Then he created a database (image library) using Hyper Text Markup Language (HTML). He used several images including at least one representative image of the problem. He arranged images in the database logically so that anyone can identify his/ her plant's problem matching it with the images of the library of the application. All the images of a problem were linked with the solution of the problem. Solution came out on clicking the image identified. Initially, it was used as a device responsive database both in online and off-line mode to identify plant's problem. Later android based *Krishoker janala* mobile application was developed and got user response. This initiative had got a significant popularity among the farmer. The number of user was about 1 million (Codex, 2017). One of the major uniqueness of *krishoker janala* was- it gave the opportunity of detecting problem images by the users themselves.

The study found that two versions of the application were available in the google play store viz *krishoker janala* (Codex, 2017) and *krishoker janala new* (Codex, 2020). The study also found that more than 50,000 downloads for each version, 800 reviews for old version and 250 reviews for new version as on 15 June 2020. Among the reviewers (N=421) 80.04% reviewed *kriskoker janala* as highly effective, 12.58% as moderately effective and 7.38% as less effective. These results were very much closer to the results found from interview where (n=330) 84.62%, 11.54% and 3.85% respondent found *kriskoker janala* as highly effective, moderately effective and less effective, respectively (Figure 1).

Malek (2015) reported that 94% user respondents had the opinion that the new intervention (*krishoker janala*) was most suitable for them, through using the database cost of delivering service or having service (up to 86%), time needed for delivering service or having service (up to 66.67%) while average number of visit (48%) was reduced.

Sultana *et al*. (2019) studied the effectiveness of '*krishoker janala'* image-based plant disease detection System (database) and reported that 64.2% of the user respondents perceived that use of *krisoker Janala* is moderately effective while 24.5% and 11.3% of them perceived as less and high effective respectively.

Our study found that the study conducted by Sultana *et al*. (2019) was only on the service provider Sub-Assistant Agriculture Officer (SAAO) who were trained on various services of DAE not much dependent on *krishoker janala* app. But our study was on the actual user including farmer and SAAOs and found more effectiveness than the study of Sultana *et al*. (2019). Our study also found that user could identify the problem of their crops on the spot using *krishoker janala* mobile application.

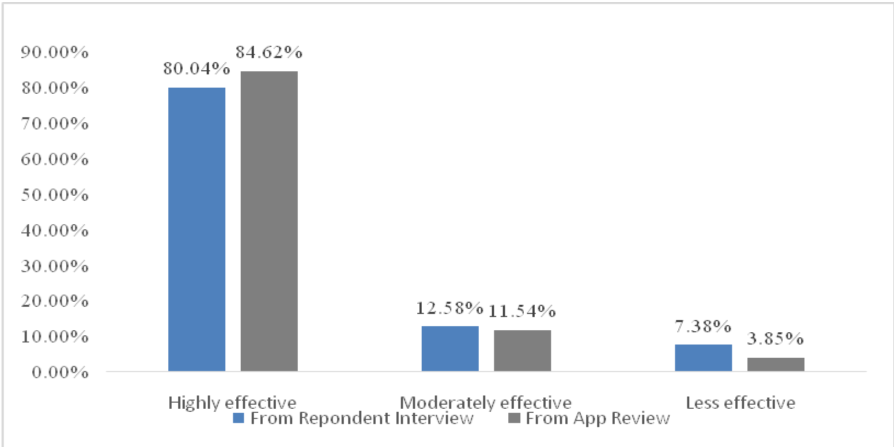


Figure 1 Level of satisfaction of *kriskoker janala* app user in percentage (%)

Degree of effectiveness varies with user group. How much variation depends on the characteristics of users- is a matter of another research. This study covered some of them. The application is effective but respondent have more recommendations as reflected in the following review:

''Very useful app that's very much helpful to farmers and also to the general peoples. A general person can treat any disease/insect affected fruits or vegetables trees by using this app, but I will personally request to the authority to add more information about disease, insects affect, and also update the apps regularly....''

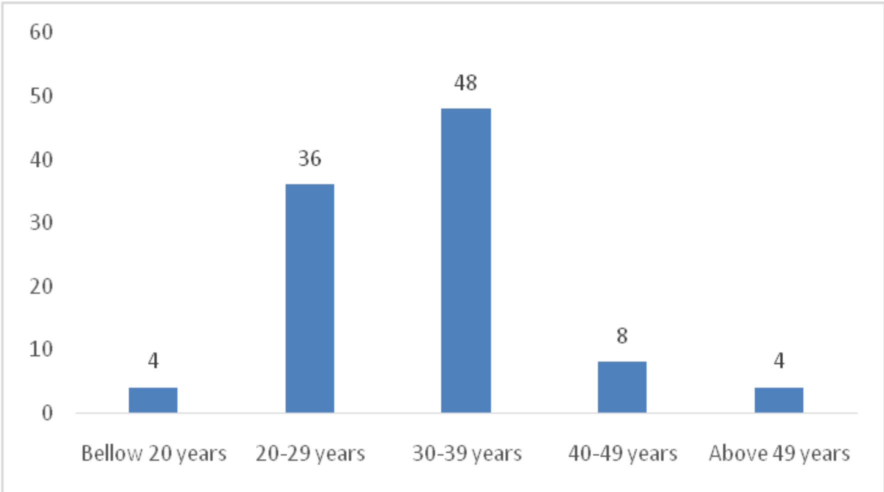


Figure 2 Age distribution of user in percentage (%)

The age distribution of the user respondents is shown in figure 2. Here it is seen that most of the user respondents belonged to the age group of 30-39 years (48%) and 36% respondents were within the age range of 20-29 years. Among the user respondents 84% belong to the age range of below 40 years. Therefore, a conclusion can be drawn that comparatively youngers were interested to use e-agriculture application like *krishoker janala.*

The figure 3 shows the educational qualification of the user respondents. It is seen that among the respondents there were no illiterate respondent, 64% respondents had higher education, 4% respondents had primary education, 24% respondents have secondary education and 8% respondents had higher secondary education. Therefore, a conclusion can be drawn that usually educated farmers are interested to use *Krishoker janala* app.

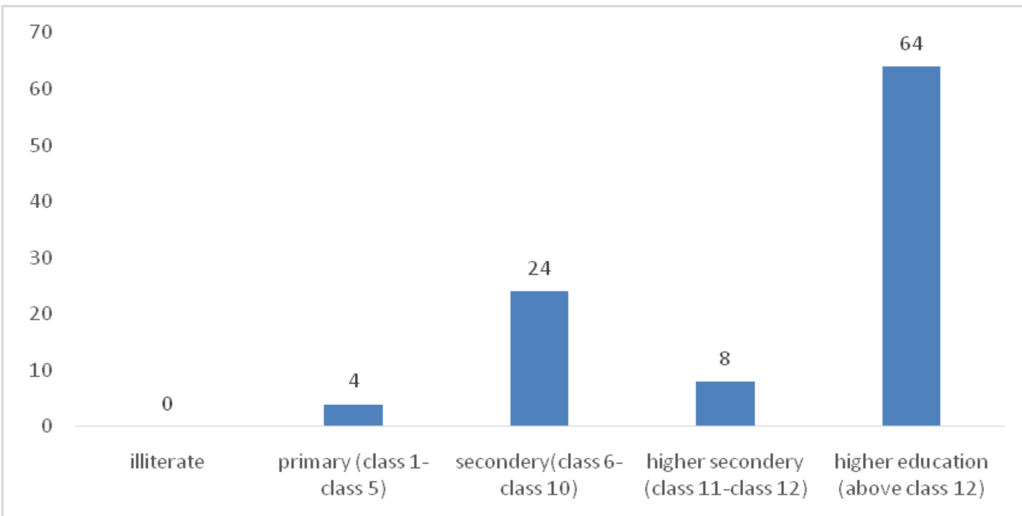
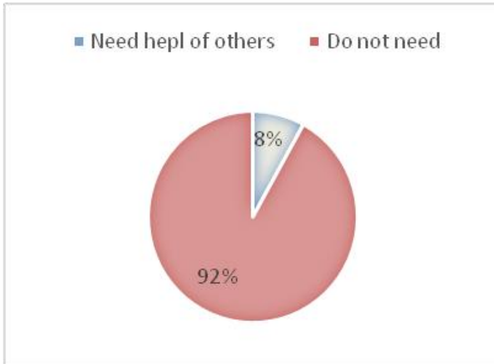


Figure 3 Educational qualification of the user respondent in percentage (%)

Problem solving capacity of the users are shown in figure 4.1 and 4.2. Figures reveal that 92% respondents could solve their plants' problem using *krishoker janala* app; did not need help from other and only 8% respondent opined that they needed help from others. These figures give a clear indication that *krishoker janala* app had created capacity among the users to solve the problems of their crops. It is also seen that almost all the respondents (94%) got timely service by using *krishoker janala* app. Our observation found many users to solve the problem of their crops instantly using *krishoker janala* app at field level. Following review is the respondent's comment in this regard:

''It's an agricultural instrument. This is the best agricultural app in Bangladesh I have ever found. It contains original photo of disease and it prevention. I would like to thanks to the governing body for this nice app.''



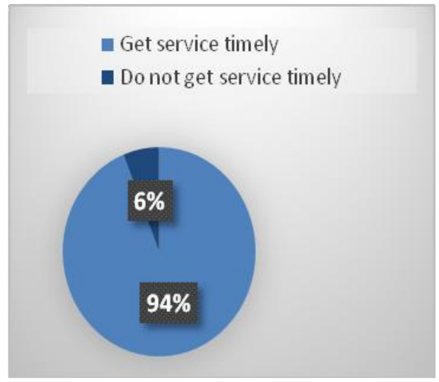


Figure 4.1 & 4.2 Problem solving capacity of the users in percentage (%)

The study shows that 95% respondent were in the opinion that time required in getting service reduced for using *krishoker janala* app, 91% and 77% respondent thought that cost and visits required for receiving agricultural services had been reduced by using *krishoker janala* app (figure 5). It shows that the app had reduced the time, cost and visit of the users and it also indicates the increased effectiveness of the app.

The figure 6 shows the type of problems faced by the app users. It is seen that 26.77% respondents mentioned that content not updated. 12.63% respondents had mentioned the system is not automated. 17.68% respondents faced problem in detecting pest and disease. 12.63% faced difficulties in using with updated android version (android 8.0 and above), 19.19% and 11.11% respondents mentioned faulty registration system and bigger size of the app as problem, respectively.

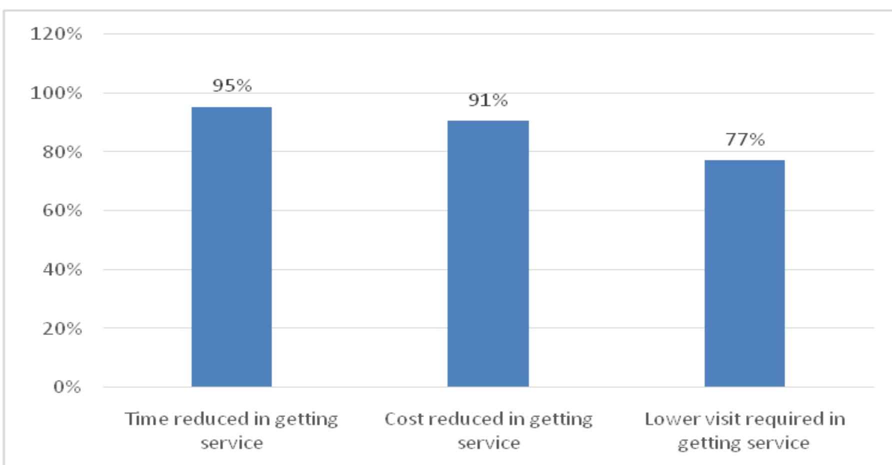


Figure 5 Users response regarding reduction of time, cost and number of visit in getting service in percentage (%)

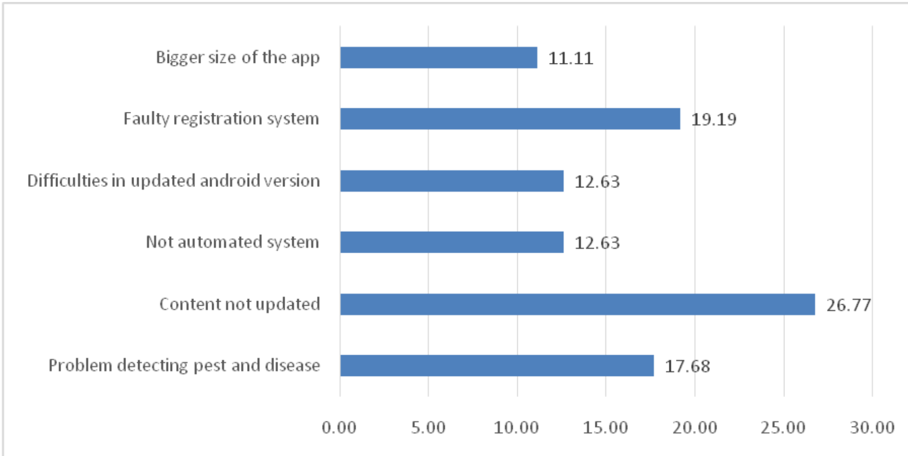


Figure 6: Types of problems faced by the users in percentage (%)

Figure 7 shows the recommendations from the users for the advancement of *krishoker janala* and to make it more effective to the users. 23.33% respondents have mentioned that the farmers should make inform about this app they recommended campaign and promotion of the app, 22.73% respondents have suggested for making available for all platform (e.g. iOS, windows) to cover more user group, 23.03% respondent suggested incorporating feedback and sharing option so that user can provide feedback and share the content to the social media, 19.70% respondent suggested updating information regularly, 9.70% recommended providing information on production technology and 2.12% of the respondent recommended automated detection system. For the sake of farmers benefit through using ICT, these recommendations from farmer should be taken into consideration.

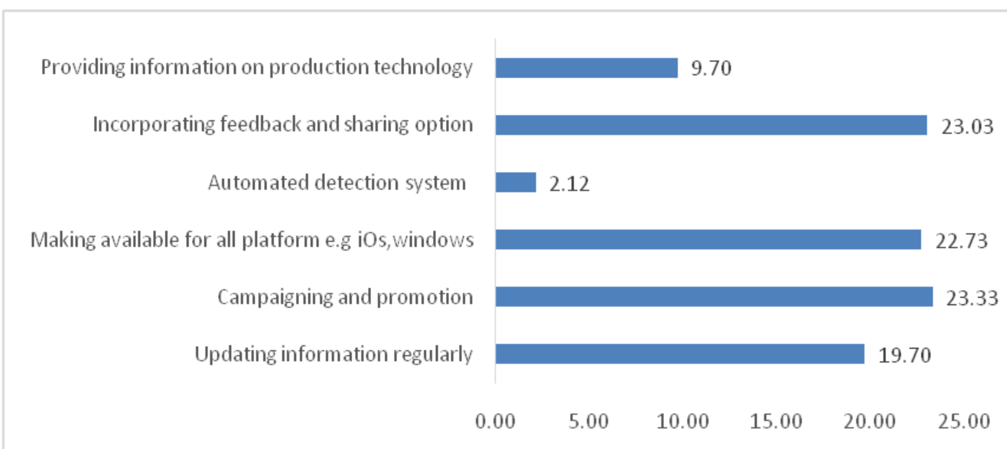


Figure 7 Recommendations from users of *Krishoker janala* app in percentage (%)

Sustainable agriculture and krishoker janala

The innovator of the initiative Malek (2015) reported that *Krishoker janala* has tried to ensure environment and public health friendliness through providing content accordingly. He claimed that some messages were tried to be conveyed to the farmer titled Farmer's Behavioral Change Communication (FBCC). Those messages were desired to bring a positive change in farmers' behavior encouraging farmers adopt environment and public health friendly farming practices and gave up environmentally harmful practices. Consequently, incidence of pest and disease were desired be reduced. Ultimately, the need for using chemical pesticides were also desired be reduced. Because of this, the risk of environment and public health were desired to be reduced. Our study found that, the solution provided in *krishoker janala* app included information about what to do immediately and what to do next i.e. a complete package of solutions provided there. The app also has emphasized biological control of pests. The user guide has provided adequate precautionary measures for the users. Our study also found that Digital Empowerment Foundation acknowledged *krishoker janala* mobile application as *Manthan South Asia* award runner up in environment and green energy category for its environment friendly approaches (DEF, 2017).

Conclusion

The study reveals that 84.62%, 11.54% and 3.85% user respondents found *kriskoker janala* application as highly effective, moderately effective and less effective, respectively. The application found to be effective in detecting plant's problem and it also saved time, cost and number of visit of farmers in getting agricultural services. The study also found that 92% respondents could solve their plants' problem using *krishoker janala* application; did not need help from others. These figures give a clear indication that *krishoker janala* application had created capacity among the users to solve the problems of their crops. It was also seen that almost all the respondents (94%) got timely service by using *krishoker janala* application. It was an exceptional experience of Bangladesh in the field of image-based plant disease detection. The study also found that user respondents reported some problems like- content not updated, the system is not automated, difficulties in using with updated android version (android 8.0 and above), faulty registration system, bigger size of the app etc. they also provided some recommendations for further improvement of the application like campaigning and promotion of the application, making available for all platform (e.g. iOS, windows) to cover more user group, incorporating feedback system and sharing option so that user can provide feedback and share the content to the social media, updating information regularly, providing information on production technology automation of disease detection system etc.. Recommendations should be taken to action by the policy maker of the country to make the application more effective to the users. To incorporate automatic disease detection system IT-industry should be included into collaboration.

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References

Abramoff, M. P. Magalhães and S. J. Ram. 2004. Image Processing with ImageJ. *Biophotonics International.* 11: 36-42.

Barbedo J. G. A. 2016. A review on the main challenges in automatic plant disease identification based on visible range images. *Biosystems Engineering.* 144: 52-60

Codex Software Solution Ltd. 2017. *Krishoker janala* (version 1.2) [Mobile app] [Accessed 15June2019].https://play.google.com/store/apps/details?id=com.dhdel.codex.krishokerjanala

Codex Software Solution Ltd. 2020. *Krishoker janala* (version 1.7) [Mobile app] [Accessed 15 June 2020]. https://play.google.com/store/apps/details?id=com.dhdel.codex.krishokerjanala

Degital Empowerment Foundation. 2017. Manthan South Asia Awards. Available at http://manthanaward.org/wpcontent/uploads/2017/02/MANTHAN-award-book-2016-17_web-version.pdf. Accessed on 15th June 2020.

Dresch, A., D. P. Lacerda, and P. A. C. Miguel. 2015. A Distinctive Analysis of Case Study, Action Research and Design Science Research. *Revista Brasileira De Gestão De Negócios Review of Business Management*, São Paulo, 17(56): 1116-1133.

Erlandson, D.A., E.L. Harris, B.L. Skipper and Allen, S.D, 1993. *Doing naturalistic inquiry: a guide to methods*. Sage Publications. pp. 44-73.

Ferentinos, K.P.2018. Deep learning models for plant disease detection and diagnosis. *Computers and Electronics in Agriculture*. 145: 311–318.

Guba, E.G. 1981.Criteria for Assessing the Trustworthiness of Naturalistic Inquiries. *Educational Communication and Technology Journal.* vol. 29 pp. 75–91.

Islam, M., A. Dinh, K. Wahid and P. Bhowmik. 2017. Detection of potato diseases using image segmentation and multiclass support vector machine. In Proceedings of the 30th IEEE Canadian Conference on Electrical and Computer Engineering, Windsor, ON, Canada, 30 April–3 May 2017; pp. 1–4.

Lukoff, D., E. David and Miller. 1998. The Case Study as a Scientific Method for Researching Alternative Therapies. *Alternative Therapies in Health and Medicine*. Vol. 4. pp. 44-52.

Maanen, J. V. 1983, *The fact and fiction in organizational ethnography, in: Qualitative methodology*, J. Van Maanen, ed., Beverly Hills: Sage, pp. 37–55.

Malek, M.A. 2015. Designing a Picture-based Agricultural Extension Tool Krishoker janala (Farmer's Window) for Better Agricultural Advisory Service. *Bangladesh Journal of Extension Education*,27(1&2): 35-40.

Malek, M.A. 2015. Impact of Using Pictorial Database Krishoker janala in providing Agricultural Advisory Services. *Bangladesh Journal of Extension Education*, 27(1&2): 93-101.

Mohanty SP, D.P. Hughes and M. Salathé. 2016. Using Deep Learning for Image-Based Plant Disease Detection. *Frontiers in Plant Science*. 7:1419. doi: 10.3389/fpls.2016.01419

Ramcharan, A., K. Baranowski, P. McCloskey, B.Ahmed, J.Legg and D.P. Hughes. 2017. DeepLearning for Image-Based Cassava Disease Detection. *Frontiers in Plant Science*. 8:1852. doi: 10.3389/fpls.2017.01852

Revathi, P. and M. Hemalatha. 2013. An Improved cotton leaf spot diseases detection using proposed classifiers. *International Journal of Engineering Research and Technology* (IJERT), 2(12): 2144-2148.

Rupavatharam S., Srikanth, A. Kennepohl and Alexaander. 2018. Automated plant disease diagnosis using innovative android App (Plantix) for farmers in Indian state of Andhra Pradesh., conference paper presented at International Congress for Plant Pathologists held on 29 July-3 August 2018 at the Sheraton Boston Hotel, Boston, USA.

Shenton, A. 2004. Strategies for Ensuring Trustworthiness in Qualitative Research Projects. *Education for Information*. 22: 63-75.

Sultana, M.S. M.S.Ali, Islam, M.H., Kabir and M.K. Hasnat. 2019. Effectiveness of Krisoker Janala in Disseminating Agricultural Information: An Innovative Tool. *Open Journal of Social Sciences.* 7: 272-280

Tana, D.S, Leongb, R. N Lagunac, C. A. Ngoa, A. Laob, D. M. Amalind, Dionisio G. Alvindiah. 2018. *AuToDiDAC: Automated Tool for Disease Detection and Assessment for Cacao Black Pod Rot*. Crop Protection vol. 103 pp. 98–102

Teegavarapu, S., J.D Summers and G.M. Mocko. 2008. Case Study Method for Design Research: A Justification. Proceedings of the ASME Design Engineering Technical Conference held on 3-6 August 2008 organized by American Society of Mechanical Engineers at Brooklyn, New York, USA.

Yin, R.K. 2003. *Case study research: Design and Methods*, Sage Publications. pp. 19-53.

Lu, Y., S.J.Yi, Zeng, N.Y.Liu and Y. Zhang. 2017. Identification of rice diseases using deep convolutional neural networks. *Neurocomputing*. 267: 378–384.