DOCUMENTATION AND VALIDATION OF BIOTIC AND ABIOTIC INDICATORS USED BY FARMERS FOR WEATHER PREDICTION IN WAYANAD DISTRICT, KERALA

by

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(2013-20-103)

THESIS

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DECLARATION

I, hereby declare that the thesis entitled **"Documentation and validation of biotic and abiotic indicators used by farmers for weather prediction in Wayanad District, Kerala"** is a bonafide record of research work done by me during the course of research and the thesis has not been previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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Certified that this thesis entitled **"Documentation and validation of biotic and abiotic indicators used by farmers for weather prediction in Wayanad District, Kerala"** is a record of research work done independently by Ms. Anju R (2013-20-103) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship with any other person.

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SYMBOLS AND ABBREVIATIONS

%	Percentage
et al.	and other people or things
EU	Extent of Use
FGD	Focus Group Discussion
ICAR	Indian Council of Agricultural Research
IIRR	International Institute for Rural Reconstruction
IK	Indigenous Knowledge
IMD	India Meteorological Department
ITK	Indigenous Technical Knowledge
KAU	Kerala Agricultural University
NCAER	National Council of Applied Economic Research
PR	Perceived Reliability
PU	Purpose of Use
SMS	Subject Matter Specialist
T. V.	Television
UVS	Use Validity Score
viz.	That is to say

INTRODUCTION

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CHAPTER 1

INTRODUCTION

Weather is certainly the most important factor determining the success or the failure of agriculture. This is mostly because, it forms the only factor over which man has no control. It directly influences the growth, development and yield of crops. Three fourth of the annual loss in farm production is both directly and indirectly influenced by weather, as reported by Verma (1998).

However, the crop losses can be reduced substantially by making adjustments through timely and accurate weather forecasting. It has been practiced by humans for millennia and is an aid to decision making under conditions of uncertainty. It is well known that, before the advent of modern methods of weather forecasting, the rural communities observed atmospheric conditions, astronomic and relief features to predict weather over short and long periods of time. The correct predictions are dependent upon the correct interpretation of indicators which are based on experience, skills and insights of people, applied to minimizing the risks rather than maximizing profits.

Weather forecast describes the anticipated meteorological conditions for a specified place (or area) and period of time. An alternative and more probabilistic definition states that, weather forecast is an expression of probability of a particular future state of the atmospheric system in a given point or territory (WMO, 2010). Farmers are very astute weather watchers and they use different kinds of indigenous knowledge to predict weather. These are mostly based on their observation on various abiotic and biotic indicators such as formation of halo around the moon, wind and cloud movement, lightning, appearance of sky, bird and animal behavior and insects movements etc.

Indigenous knowledge is the sum total of knowledge and practices which are based on people's accumulated experience in dealing with situations/ problems in various aspects of life and such knowledge and practices are special to particular culture (Wang, 1988). This knowledge is generally passed down from generation

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to generation by experimental learning and by word of mouth and is, for the most part, undocumented in written form.

Local indicators and local knowledge systems cannot be replaced with scientific knowledge, because they are holistic and specific to local situations that provide farmers with the ability to make decisions and plan in advance. Therefore, identifying the indigenous weather forecasting indicators and acquiring information on how they are used by farmers will help to improve crop production and can be promoted as a climate change mitigation strategy.

Need for study

The indigenous traditional knowledge (ITK) is depleting day by day because of lack of awareness about its value and impact, as well as proper documentation. ITKs being part of the community knowledge domain, they are not documented and are mostly transferred orally across generations. Therefore, there is urgent need for proper documentation of these valuable resources as they can contribute significantly to climate resilient strategies and their effectiveness in location based weather prediction.

Scope and importance of the study

The study will provide an exhaustive list of biotic and abiotic indicators used for weather forecasting. Further, it will give a thorough understanding of the awareness and adoption of indigenous knowledge by the farmers. Finally, the study will reveal the attitude of the farmers towards indigenous and scientific weather forecasting.

Objectives

The objectives of the study are;

1. To document ITKs based on biotic and abiotic indicators used by farmers in weather prediction.
2. To validate and assess the documented ITKs through farmer participatory processes and published research findings.

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3. To rank and evaluate the scope of validated ITKs in local crop weather forecast based on farmer perception.
4. To assess the accessibility and perceived reliability of weather forecast from agricultural department and IMD by farmers.

Limitations of the study

The key informants and farmers were found scattered throughout Wayanad. Most of them were not accessible by motorized vehicle and must be reached by foot. And the area of investigation is restricted to one District; therefore, the findings have to be viewed in specific context and should not be generalized for a wider geographical area.

The time factor, which is crucial for any study, was another limitation. Since respondents were illiterate and reluctant to share whatever quantitative information they knew, data collection was constrained to that extent. Since this study was based on perception and expressed opinion of the respondents, some personal bias becomes inevitable. However, every care was taken to avoid this and make the study as objective as possible.

Presentation of the study

The report of the study is presented in five chapters. The first chapter deals with introduction, where in the statement of the problem, need, scope and limitations of the study are discussed. The second chapter covers the review of the studies related to the present study. The third chapter is the methodology which encompasses the details on selection of the study area, sampling, data collection procedure, selection of variables, empirical measures used, design of the research, statistical tools used etc. In the fourth chapter, the results in relation to objectives with interpretation of the findings and discussion are presented. The fifth chapter summarizes the study highlighting the salient findings. The references, appendices and abstract of the thesis are given at the end.

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REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

This chapter deals with the review of literature. A comprehensive review of relevant literature is imperative in any scientific investigation. This helped to give proper orientation of the study and also to place the problem on a theoretical perspective. The same has been presented under the following headings that enable better understanding of the subject.

2. 1. Indigenous Technical Knowledge (ITK)
2. 2. Abiotic indicators for weather prediction
2. 3. Biotic indicators for weather prediction
2. 4. Validation of Indigenous Technical Knowledge in weather forecasting
2. 5. Accessibility and perceived reliability of weather forecast among farmers

2.1 Indigenous Technical Knowledge (ITK) in agriculture

Wang (1988) defined ITK as the sum total of knowledge and practices which are based on people's accumulated experience in dealing with situation problems in various aspects of life and such knowledge and practices are special to particular culture.

According to Warren *et al.* (1989), ITK is a knowledge that is unique to a given culture and society. This knowledge is the information base of that society, codified in the language of the society and it facilitates communication and decision- making.

ITK is the basis for local-level decision making in agriculture, health care, food preparation, education, natural-resource management and a host of other activities in rural communities (Warren, 1991).

Indigenous knowledge is the unwritten and untapped body of language which is held in different brains, languages and skills in as many cultures, groups, languages and environments (Atte, 1992).

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Identifying, documenting and incorporating indigenous knowledge systems into agricultural extension is essential in order to achieve sustainable agricultural development (Kanagasabapathi, 1993 and Rajasekaran *et al.*, 1993).

As per Ulluwishewa (1993) ITK is the knowledge that people have gained through inheritance from their ancestors. It is a people derived science and it represents people's innovations, skills and creativity.

Fernandez (1994) indicated that the terms 'local' and 'indigenous' knowledge are used to refer to that knowledge which is generated and transmitted by communities, over time, in an effort to cope with their own agro- ecological and socio- economic environments.

Talawar and Singh (1994) observed that the agricultural practices followed by the farmers that are evolved locally, and inherited over a long period of time are referred to as indigenous practices.

Somasundaram (1995) referred to IK as the traditional knowledge that is based on accumulated experience, much fitted to the local situation and social system.

International Institute for Rural Reconstruction (IIRR) (1996) defines indigenous knowledge as the knowledge that the people in a given community have developed over time and contributes to develop which is based on the experience, often tested over centuries of use, adapted to local culture and environment and is dynamic and changing.

Kanagasabapathi (1996) opined that indigenous agricultural practices are cost-effective, time-tested, eco-friendly and they serve to sustain the agricultural development.

Lawas and Luning (1996) described IK as a type of knowledge that has evolved within the community and has been passed on from generation to another. Sithole (2007) conceptualized that IK is predominantly tacit, embedded in the practices and experiences of its holders commonly exchanged through personal communication and demonstrations from the teacher to the apprentice, from parents to children and from neighbour to neighbour.

Rambabu (1997) defined the indigenous technologies as the technologies developed by the local farmers based on the topography, local agro- climatic conditions and available resources through non-formal experiments.

Brouwer (1998) pointed out that ITK is unique, traditional local knowledge existing within and developed around the specific condition of women and men indigenous to a particular geographic area. Indigenous knowledge is stored in peoples' memories and activities and is expressed in stories, songs, folklore, proverbs, dances, myths, cultural values, beliefs, rituals, community laws, local language and taxonomy, agricultural practices, equipments, materials, plant species and animal breeds. IK is shared and communicated orally. Indigenous forms of communication and organization are vital to local-level decision-making processes and to the preservation, development and spread of indigenous knowledge (Grenier, 1998).

Indigenous practices neither simply existed nor divinity revealed, they were researched and developed by the practitioners themselves which is an important factor for sustainable system, explained by Kashyap *et al.,* (2000).

ITK is a community based functional knowledge system developed, preserved and refined by generations of people through continuous interaction, observation and experimentation with their surrounding environment. It is a dynamic system, ever charming, adopting and adjusting to the local situations and has close links with the culture, civilization and religious practices of the communities (Pushpangadan *et al.*, 2002).

Blending the results of informal experimentation with age old experience gained by farmers has resulted in adoption of many practices that are commonly known as ITK (Singh and Dwivedi, 2003).

Indigenous knowledge is collectively owned and it exists as agricultural and medicinal practices, stories, songs, folklore, proverbs, cultural values, taboos, norms, languages, and rituals (Nakata and Langton, 2005).

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Somasundaram (2005) opined that ITK is region specific; it can be applicable to similar agro climatic conditions because, most of the indigenous agricultural technologies have got scientific rationale.

According to Muthuraman *et al.* (2009), ITK is specifically concerned with actual application of the thinking of the local people in various operations of agriculture and allied areas.

Goldman and Lovell (2017) defined ITK as knowledge about the local environment that is produced, held and used by indigenous people and communities.

2. 2 Abiotic indicators for weather prediction

Farmers use various abiotic indicators for predicting the weather based on observations, theoretical calculations, planetary configurations etc. This includes observations on sun, moon, clouds, sky, wind, lightning, rainbow, etc.

Indicators used for rainfall/ flood prediction

Kanani (2004) in a study on traditional meteorological principles in Saurashtra reported that, farmers of the region gave more weight to prediction of the onset of monsoon based on wind direction. She reported that, observations on the wind direction on *Akshaya Tritiya* (third day of *Vaishaka* month) from 3 to 6 a. m. were used to predict the rainfall pattern and expected crop yield for the year.

Singh and Dorjey (2004) documented 28 agricultural proverbs, that are commonly used in Utter Pradesh, of these 50 per cent were related with rainfall prediction.

Anandaraja *et al.* (2008) documented various ITKs related to rainfall, they are

- Morning cloud and evening thunder indicate rain and high sweating at day time will bring the rainfall at night
- Ring around the moon is used as an indicator of rain

Rengalakshmi (2008) documented many indicators for predicting rainfall, they are

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- During evening, if the lower cloud appears red followed by black cloud at the top, expect rain in another two days
- Black cloud with no stars is a good indicator for predicting rainfall
- In December- January, if the clouds appear black, third day it will rain
- If lightning occurs from east, west and south, expect rain immediately
- If lightning comes in opposite direction (East to West), expect rain in another one hour

Shankar *et al.* (2008) documented different ITKs for predicting rainfall, they are

- Halo around the moon indicates rainfall
- Seasonal reversal of wind direction is long range rainfall forecast
- In N-E monsoon season, northern wind along with rain bearing clouds indicate immediate rainfall
- Rainbow in the West during S-W monsoon, indicates upcoming rain

Varshneya *et al.* (2009) claimed that, among various astro- meteorological methods for forecasting rainfall, the "*Anthariksha* (Atmosphere) method" is most popular, which is based on sky observations.

- Cool winds with moisture trigger saturation with already existing clouds result heavy rains
- Pink colored sky in the evening indicates rainfall (short range rainfall forecast)
- Rainbow in sunny weather indicates rainfall

Chinlampianga (2011) documented many abiotic indicators for weather prediction, they are

- Red clouds seen at sunset in western direction, rain is predicted to come within 3-4 days

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- Dark clouds preceding strong winds indicate thunderstorms in a few hours
- Dark clouds indicate heavy rain within a few hours
- Red color dominating in the rainbow during June/July, indicates more rains to come

Sivanarayana and Vani (2011) claimed that, if it rains in the night at the beginning of "*Arurdra*" constellation, then the future occurrence of rain will be during nights only. And based on cloud colour, distance and movement, farmers can decide the occurrence of rain. Presence of more dark coloured clouds without wind and closure to the earth indicates occurrence of rain within 2- 3 hours. Presence of red clouds in the western side with gaps indicates that, the rain will come within 5-6 hours.

Okonya *et al.* (2013) reported different indicators for predicting onset of rainy season, they are

- Moon appears white/grey/bright with visible ring and one side of the moon is black is an indicator of the onset of the rainy season
- A feeling of excess heat during the night and day are indicators for the onset of the rainy season
- A group of small stars in the east indicates onset of the rainy season

Bordoloi and Muzaddadi (2015) documented different abiotic indicators for predicting flood in their study about ITK associated with disaster management and fisheries related activities in the highest flood affected district (Dhemaji) of Assam, India. They are: if the moon inclines south, it implies a foretelling devastating flood; if the cloud gathers in the south west direction, it indicates a probable storm; if in south east direction indicates rain and flood and in north- west direction indicates normal rain. When the rainbow extends from north east to south west sky and if its full half is clearly visible, it indicates devastating flood ahead. When cloud floats from north east towards south west, it indicates forthcoming rain.

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Sarkar *et al.* (2015) documented that, farmers in Rajasthan rely on colour of moon to predict rainfall. Pale or yellow colour moon is associated with good rainfall.

Indicators of drought/ no rainfall

Farmers in Gujarat believe that, if there is rain accompanied with lightning and mild thunder on the second day of *Jayastha* month (May - June), there will be no rain for the next 72 days (Kanani and Pastakia, 2001).

Anandaraja *et al.* (2008) documented that, dense fog in early morning indicates no rain and rainbow in the east direction indicates absence of rain.

Chinlampianga (2011) documented that, if clear sky appears, it means that rain has passed.

Sivanarayana and Vani (2011) claimed that, rain will occur in the entrance of "Arurdra" constellation, and then there will be dry spell for the coming 60 days. Black/dark colour clouds with fast movement and far from earth indicate rain will not come.

Risiro *et al.* (2012) documented that, the prevalence of *chamupupuri* [whirlwind] is associated with hot weather conditions and gusty winds and the presence of mist and dew in the morning is a sign of fine weather conditions during the day.

Sarkar *et al.* (2015) documented that, farmers in Rajasthan draw on colour of moon to predict rainfall. White and red colour moon is indicative with rainless condition.

Nair (2016) and Padre (2013) reported that, reduction in water levels in *Kenis* (small well like structures near paddy fields) will lead to drought.

2.3 Biotic indicators for weather prediction

According to Holt (1990) and Melillo *et al.* (1995), the responses of various species to climate change can be categorized as movement (if the species are mobile, they will track the suitable environment niches), adaptation (if the

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species are able to adjust to the changing conditions and have high physiological tolerances) and extirpation (when both movement and adaptation fails).

Mhita (2006) noted that, before the establishment of the modern methods of weather forecasting, the rural communities of Tanzania observed plants, animals and birds for weather forecasting.

Many studies have been carried out in the use of phenology of plants. The behavior of certain insects, birds and animals was used as reliable indicators for weather prediction. Some of the major works related to the study are included.

Indicators used for rainfall/ flood prediction

Plants/ tress

Pisharoty (1993) reported that, Golden Shower tree (*Cassia fistula*) is a unique indicator of rain. It bears bunches of golden yellow flowers in abundance about 45 days before the onset of monsoon.

Kanani (2004) documented various tree species, that have been used as indicators of monsoon by the local communities, they are

- Appearance of good foliage in Darbha grass (*Eragrostis cynosuroides)* indicates good monsoon
- Good foliage of Pipal (*Ficusre ligiosa)* indicates adequate rain
- Good foliage of Indian butter tree (*Madhuca latifolia)* indicates good monsoon

Kumari (2008) reported that, if bundles of stored Sal leaves soften, rainfall will commence within 3-5 days.

Acharya (2011) reported that, plants and certain fungi can accurately forecast the wet or dry weather. A type of edible mushroom (*Pleuorotus ostreatus)* growing on stems and tree trunks expands prior to a rain. He has also documented many other biotic indicators for weather prediction such as:

- The medicinal plant *Morinda angustifolia* exudes nectar heavily before a rain

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- Increased length of internodes of *Cassia fistula* and the increased length of the corolla tube in *Costus speciosus* are used as indicators for onset of rainy season
- Early unusual flowering of *Hydrocotyle javanica* in marshy area is used to predict upcoming rain
- Scabrous character of stem and leaves of *Hyptis suaveolens* in dry as well as marshy area is used to predict upcoming rain
- Increased length of corolla tube of *Costus speciosus* in upper dry land indicates flood or typhoon
- Yellow color of inflorescence of *Lantana camara* in marshy area indicates flood or typhoon

Pareek and Trivedi (2011) reported that, in Rajasthan flowering and generation of new leaves in *Ficus* species indicate early onset of rainfall.

Singh (2011) documented different plants for predicting the weather in Manipur, Northeast India.

- If Deccan hemp (*Hibiscus cannabinus*) bears a large number of flowers; it is presumed that, the rainfall for the year will be good. If it stops producing flowers, it indicates the ending of rainfall for the year.
- If mango trees (*Mangifera indica* Linn.) profusely flower with dark green leaves at the beginning of season, it indicates heavy rainfall.

Flowering of *Cordia africana*, *Amorphophallus abyssinicus* and *Albizia-gummifera* was reported as very reliable indicator for predicting rainfall (Chengula and Nyambo, 2016).

The phenology of Tedecha (*Acacia tortilis*) and Aloe vera (*Aloe indica*) is used to forecast the rainy season. In both cases, herders expect rainfall a month after the date of flowering of these trees (Ayal, 2017).

Amphibians, insects, birds and mammals

Golakia (1992) found that, observations on the behavior of specific birds and animals are used as indicators of rain. They are

- Chameleon (*Kachinda*) climbs the tree and assumes black-white-red colors which indicate immediate rain
- Frogs start singing in the initial days of the *Jayestha* (May) indicates early rain
- Sparrow bathing in dust indicates good rain
- Peacocks crying frequently indicates rain within a day or two

Rahudkar (1998) reported that, farmers of Maharashtra believe that, large number of fireflies seen at night on the trees is a sign that, the monsoon will start early.

Crick (2004) claimed that, the avian species had the capacity to be considered important bio-indicators, which was easily understood by the public and policy makers, since birds were very popular and they have an iconic status throughout the world.

According to Walsberg (1993), weather affects the metabolic rate of birds directly and indirectly, which influence birds' behavior. Important activities like feeding and breeding would be reduced due to unfavorable climates. Indirect effect on bird activity and behavior induced by the changes in temperature and humidity was also reported by Crick (2004).

In traditional weather forecasting in Tripura, the onset of rainy season and upcoming rain are also indicated by the unusual behavior of certain birds, the beginning of the rainy season is signaled by the unusual chirping of the black- throated sunbird (*Aethopyga saturata*), orange- bellied leaf bird (*Chloropsis hardwickii*), grey-headed canary flycatcher (*Culicicapa ceylonensis*) (Acharya, 2011). He also documented different indigenous practices based on behavior of certain insects and birds for predicting weather. They are:

- Exodus of ants from their caves indicates onset of rainy season
- Native frogs croaking near swampy areas and hiding their egg indicate upcoming rain
- Insect migrating to mountain predicts adverse weather conditions such as flood or typhoon
- Dragon fly flying low indicates upcoming rain
- Apex of the mound getting moist is used as an indicator for predicting upcoming rain
- Wasps hiding their honey comb indicates upcoming rain
- Spider spinning shorter and producing thicker webs indicates adverse weather conditions such as flood or typhoon
- Chicken staying under shade at noontime and seem like taking bath with dust are used as indicators for predicting upcoming rain
- Peacock making sound early in the morning and late in the evening indicates upcoming rain

Chinlampianga (2011) reported that, when winged termite (*Reticulitermes sp.)* comes out of the soil in a group after a rainfall, it is believed that, rain will not come again for some time. If there was no rain in the previous day or week but the insects are coming out of the soil, rain is expected to come soon. He also found that new soil particles outside the holes of field cricket Perhpawng *(Gryllus pensylvanicus)* during the dry season indicated immediate rains.

Dixit and Goyal (2011) documented that, centipedes emerging from their holes carrying their eggs in groups indicate early rainfall and if dragon fly swarms in a large group over water surface, a dry weather is predicted, if they swarm over an open dry land rainfall is predicted.

Nedelcheva and Dogan (2011) documented that, the emergence of a larger number of *Erigeron canadense* predicts the occurrence of bad summer and when *Achillea* species blooms abundantly, it indicates good winter in Bulgaria in Southeast Europe.

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Sethi *et al.* (2011) documented that, if snails climb in certain trees, earthworm crawls plenty in and around and insects fly around, these indicate that there would be cyclonic storms followed by heavy rain.

Muguti and Maposa (2012) reported that, certain species of brownish frogs known as *machesi*or *dzetse* (bull frogs) are used to predict the intensity of rains. If they appear in large numbers in a particular *gandwa* (water pond), it is an indicator of high rainfall patterns in a given locality.

Indicators of drought/ No rainfall

Plants/ trees

ICAR (2004) documented that, farmers of Bhavnagar, Surendranagar and Kheda district of Gujarat use Kerda (*Capparis decidua*) flowers for predicting drought. When the kerda plants produce more number of flowers and fruits, it is assumed that, there will be severe drought in the coming year. The report also testified the belief of the farmers of Gourangatilla and Teliamura villages of West Tripura that, flowering of bamboo follows severe drought.

Kanani (2004) reported that, heavy foliage of Khejro (*Prosopis cineraria)* indicates drought.

Singh *et al.* (2006) reported that, Khair trees (*Acacia catechu*) showing extra bushy growth habit and sprouted wild cucumbers everywhere indicate drought.

Acharya (2011) reported, that a type of edible mushroom (*Pleuorotus ostreatus*) growing on stems and tree trunks shrink in dry weather.

Amphibians, insects, birds and mammals

Snowy tree cricket is the one whose chirp rate can easily be used to estimate the temperature. Cricket makes their distinctive chirp related to temperature. Crickets, like all insects, are cold- blooded and take on temperature of their surroundings. Dolbear (1897) expressed the relationship as the following formula which provides a way to estimate the temperature in degree Fahrenheit from the

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number of chirp per minute. Let **T** stand for temperature and **N**, the rate per minute and a change of four chirps a minute for each change of one degree.

$$T = 50 + ((N - 40)/4)$$

2. 4. Validation of Indigenous technical knowledge (ITK) in weather forecasting

Though validation of ITK is an important aspect, which has almost been untouched from research agenda because, up-scaling or down- scaling is difficult in the case of ITKs.

Moreover, as Meyer (2009) stated the information flow in an oral context is controlled by attitudes, perceptions, norms, values and belief systems inherent to indigenous people, there are several challenges affecting the documentation and validation of indigenous knowledge.

Hiranand and Kumar (1980) concluded in a study that, it becomes necessary that the scientists investigate the rationality of each one of the technical belief held by farmers so that, they can clearly accept or reject a technical belief.

Chambers (1983) highlighted the Kenyan farmers' theories of correlation between lunar phases and rainfall, where farmers took into account the lunar phases for predicting proper time of sowing. For validating the same theory, the author studied meteorological data scientifically and strongly supported the correlation between lunar phase's influence and rainfall patterns.

Bluestein (1992) explained that, in a high pressure system sinking of air takes place, which is associated with fine weather.

ICAR (2004) checked the experimental validity of the ITK - ants transfer their eggs prior to rainfall. This ITK is being popular in several districts in Uttar Pradesh, especially in Etah, Bareilly, Buland, Badaun, Shahr and Aligrah districts for forecasting rain. The key informants mostly opined that, when ants carry eggs in large numbers, rain will be occurring the same day. Also a field study was conducted in four villages, viz. Manda and Kamua villages in Bareilly district, and Nayabas and Danpur in Bulandshahar district of Uttar Pradesh. Twelve case studies

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were carried out in the study area. Out of these 12, in 10 cases, rain occurred within 2 to 7 hours from the time the ants were observed transferring their eggs. In remaining two cases, heavy rain occurred the next day. Out of these 12 case studies, prediction of rain by observing the ants carrying their eggs appears to be valid and reliable.

The validity of ITK "sparrow frolicking on sand as natural indicator of rain" was checked by ICAR (2004). The study was conducted in Bulandshahar, Badaun and Bareilly districts of Uttar Pradesh as well as in Delhi. And the 38 observed case studies indicated that, in all the cases, clouds did appear. But rain occurred only in 24 cases (63%). So this ITK is a good indicator of clouds with possibility of rainfall.

ICAR (2004) checked the experimental validity of the ITK "when stored tamarind and *mahua* flowers soften, it indicates incoming rain shortly". The study was conducted in Dakari and Ashanpahari villages in Jharkhand. It was reported that, the ITK was accurate up to 92.5%, and being practiced by 62% of farmers. The data revealed that, when there were weight gains, it was followed by rainfall. And during dry spells, both material loss some weight or maintained their weights.

Reddish color sunset indicates fine weather. A reddish sunset means that, the air is dusty and dry devoid of condensation nuclei in the surrounding atmosphere and therefore there is no chance for precipitation (Saayman, 2008).

2.5 Accessibility and perceived reliability of scientific weather forecast based on farmers' perception

Perception is defined as the process by which an individual maintains contact with the environment (Gibson, 1959). Perception is what we want to make out from an information. Different people perceive different things about the same situation. Perceptions vary from person to person.

Kulkarni (1985) claimed that, the neighbors and tribal leaders were found to be most utilized and reliable for seeking farm information and the less used and low credibility sources were radio, newspaper and magazines, demonstration etc.

NSSO (2005) conducted a situation assessment survey among farmers to identify their exposure to different sources of agricultural information. The survey revealed that, 13 per cent of farmers get agricultural information through radio, 9.3 per cent from TV, 7 per cent from newspaper and 5.7 per cent by extension worker.

Msuya (2007) reported that, younger generations that are exposed to Western education are less interested in indigenous knowledge, viewing such knowledge as outdated and primitive. Younger generations undervalue the utility of indigenous knowledge systems because of the influence of modern technology and education.

Kumari (2008) reported that majority (92.5 per cent) of the respondents was medium adopters, followed by low (4.17 per cent) and high (3.33 per cent) adopters in terms of weather forecasting.

According to Lwoga *et al.* (2010) indigenous knowledge is at risk of becoming extinct if appropriate measures are not taken to manage it to assure its accessibility to future generations.

In a study conducted in Soroti – Kaabong districts of Uganda, the respondents were asked to compare the accuracy and reliability between indigenous and meteorological forecasts. The result showed that 58 per cent of population rated indigenous forecast methods as reliable compared to only 27 per cent under the meteorological approach (Komutunga *et al.,* 2013).

Kolawole *et al.* (2014) reported that, in terms of reliability of weather information, 45 per cent of the farmers affirmed that, scientific weather forecast cannot be relied upon as, it does fail most of the time.

Mudombi and Nhamo (2014) reported in their study about access to weather forecasting and early warning information by communal farmers in Seke and Murewa districts, Zimbabwe, that more than half of the respondents in the two districts indicated that they accessed weather forecasting information from weather stations, with about 72 per cent in Murewa and 54 per cent in Seke. The respondents in both districts ranked the radio as the most important channel for accessing information. Respondents were asked how they perceived the reliability of the modern forecasting information (that is information from Meteorological Service

Department). None of the respondents in Seke and only one per cent in Murewa indicated that, the weather forecasting information was 'very reliable'.

Feleke (2015) reported that, the farmers in the central rift valley of Ethiopia utilize Radio, Television, Neighbors, Village leaders and Development Agents, as sources of climate information and use the website of National Meteorological Agency (NMA), regional and zonal meteorological branch offices, Melkassa Agricultural Research Center (MARC), mass media and agricultural offices are sources of weather information. Sixty per cent of farmers got climate information through television, radio, newspaper and meetings. And 37 per cent of farmers are through District Bureau of Agriculture. And 59 per cent of the respondents mentioned that the information they get is not clear and easy to understand.

In 2014, the National Council of Applied Economic Research (NCAER) surveyed 918 agricultural households in 35 districts to find farmers' perceptions of reliability, accuracy and timeliness of ESSO-NCMRWF-IMD Weather Prediction Systems. The results showed that overall, roughly 57 per cent of the farmers felt there was an improvement in timeliness of the forecast. However, a significant segment (60 per cent) of farmers in Madhya Pradesh and Gujarat were not pleased with it. Almost 60 per cent of the farmers in both states did not think the reliability of the weather information had improved in the past four years (NCAER, 2015).

Godara *et al.* (2016) reported that, majority of the respondents in Hisar and Kaithal district in Haryana used radio, television and SMS facilities of Chaudari Charan Singh Haryana University. They considered the information credible and was rated the most preferred source for weather forecasting advisory services.

Rajesh *et al.* (2016) in the study on farmer's perception about weather forecasting advisory services reported that 43.33 per cent of the respondents had negative perception about the effectiveness of weather forecasting advisory services.

METHODOLOGY

CHAPTER 3

METHODOLOGY

This chapter deals with the description of the methods and procedures adopted in conducting the research study. The details of methodology followed are presented under the following subheadings.

3.1 Research design
3.2 Locale of the study
3.3 Sampling procedure
3.4 Data collection
3.5 Operationalization and measurement of variables
3.6 Validation of documented indigenous practices
3.7 Statistical tools

3. 1 Research design

A research design is a fundamental plan for gathering the empirical data necessary to corroborate or refute the basic conceptual framework models or theories being investigated (Hoffer and Bygrave, 1992).

Ex-post facto design was employed in the present study. According to Singh (2006), an ex-post facto research is one in which the investigators attempt to trace an effect that has already occurred to its probable causes. Though it forms a systematic empirical enquiry, the scientist does not have direct control over the independent variables.

3. 2 Locale of the study

The study was conducted in Wayanad district of Kerala (Figure 1). This district was purposefully selected for conducting the study for the following reasons.

- Wayanad is one of the four climate change hotspot districts in Kerala and affected by extreme weather events

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- Agriculture is the predominant livelihood vocation in the district. Wayanad holds the 1^{st} position in the state in the percentage of agriculture labourers to total workers (29.88%) and second in the percentage of cultivators to total workers (15.51%) (Census of India, 2011)
- Impressive ethnic diversity of the district evidenced by the presence of ten different tribal groups which forms a basic source of indigenous knowledge

3. 2. 1 Brief description of the district

Wayanad district came into existence on 1st November, 1980 as the 12^{th} district of Kerala. The name Wayanad is derived from "Vayal Nadu" which means the land of paddy fields. Wayanad district in Kerala lies between North latitudes 11 °26′to 12°00′ and East longitudes 75° 75′ to 76° 56′at altitude of 700 to 2100 meters above mean sea level in the southern tip of peninsular India. It is bounded on the east by Nilgiris of Tamil Nadu and Mysore district of Karnataka. Coorg district of Karnataka lies on the north, Malappuram district on the south and Kozhikode as well as Kannur districts of Kerala on the west. The total geographical area of the district is 2,131. sq.km. and 885.92.sq.km of the district is under forest. The population of the district is about 8,17,420 of which the tribal population constitutes 18.5 per cent and it accounts for 36 per cent of the State's tribal population. Major tribal communities found in the district are Paniyan (44.06%), Mullu Kuruman (17.34 %), Kurichian (16.10 %), Kattunaickan (11.33%), Adiyan (7.41%) and Urali Kuruman (3.13 %).

This high-altitude district is characterised by the cultivation of perennial plantation crops and spices. The major plantation crops include coffee, tea, pepper, cardamom and rubber. Coffee based farming system is a notable feature of Wayanad. Paddy is cultivated in 22,772 hectares of land. Spices like ginger, cardamom and turmeric are also cultivated to a large extent.

Wayanad is located on the verge of two climatic zones viz. per humid and moist sub-humid zones (Raju *et al.*, 2013). Annual average rainfall is 1635 mm/year, but with quite large differences between good and bad years.

Kalpetta is the headquarters of the Wayanad district administration with Civil Station and other main offices. There is only one revenue division named Mananthavady in the district. It consists of 3 Taluks viz. (1) Vythiri, (2) Manathavady and (3) Sulthanbathery and 49 revenue villages. The district has four development blocks viz. (1) Mananthavady (2) Kalpetta (3) Sulthanbathery and (4) Panamaram comprising of 25 grama panchyats. Map showing the geographical location of the district is given as Figure 1.

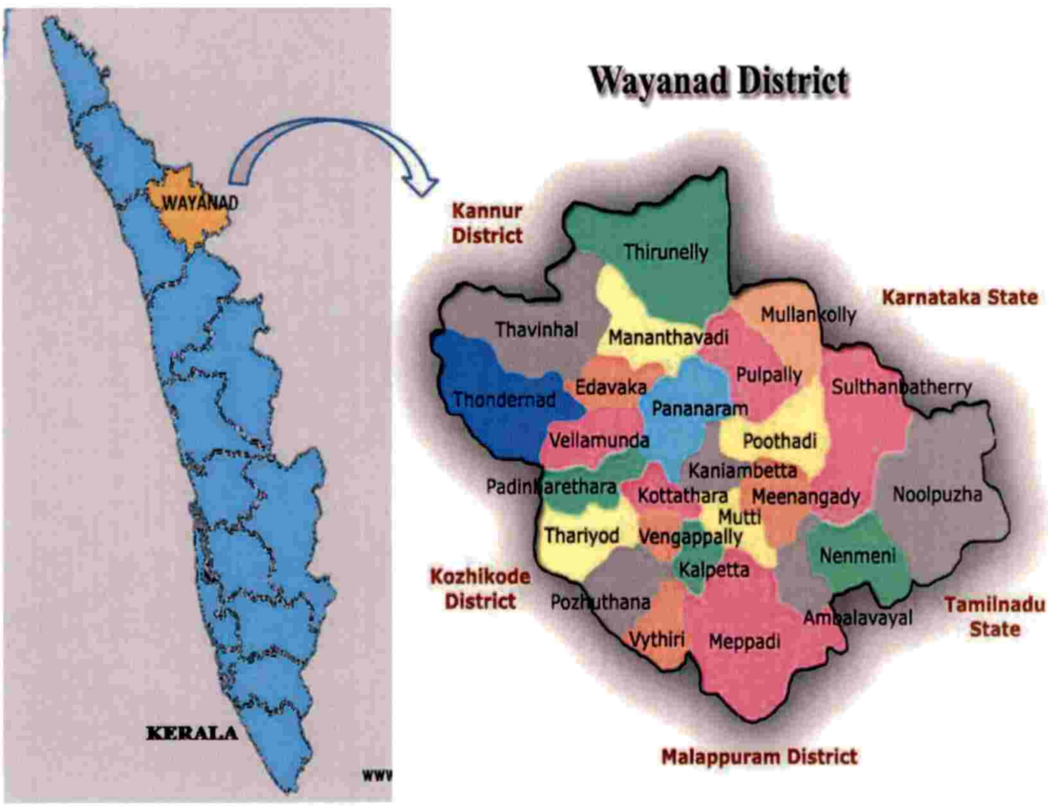

Figure 1. Map of Kerala showing the district of study- Wayanad district

3. 3 Sampling procedure

3. 3. 1 Selection of panchayats

Exhaustive sampling was followed to include all the four blocks (Mananthavady, Kalpetta, Sulthanbathery and Panamaram) of the district for the study. Based on area under cultivation and crop damage reported under natural calamity during the past three years, one panchayat each was selected from all the four blocks. Panchayat wise data on ratio of crop damage to area under cultivation

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reported for the past three years (2015, 2016, 2017) was collected for the four blocks of the district (Appendix-II). One panchayat with the maximum damage was selected from each block for the study (Figure 2), the details of which are given below.

Sl. No.	Name of block	Name of panchayat	Percentage area affected by natural calamity
1	Kalpetta	Padinharethara	31 %
2	Manathavady	Vellamunda	23 %
3	Sulthanbathery	Nenmeni	25 %
4	Panamaram	Mullankolly	35 %

(Source: Principal agricultural office, Wayanad; District office of Economics and Statistics, Wayanad)

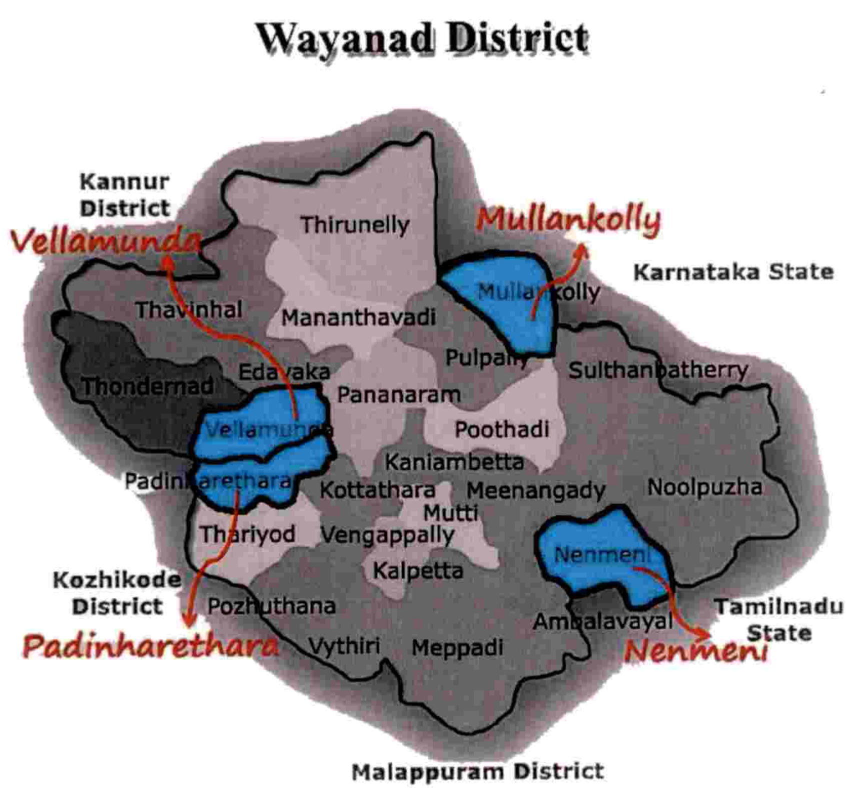

Figure 2. Map of Wayanad district showing the panchayats selected for the study

3. 3. 2 Selection of respondents

Random sampling was followed to select 25 farmers from each of the four selected panchayats to make a total sample of 100 farmers. In addition, 20 key informants were selected purposively from the Department of Agriculture Development and Farmers' Welfare, Non- Governmental Organizations working in the area viz. Wayanad district Adivasi Youvajana Samithy, Wayanad Social Service Society, M. S. Swaminathan Research Foundation, Malanad Charitable Society and Sulthanbathery Mannam Social Service Society and Farmer Interest Organization viz. *Karshagasangams/ samathy* working with traditional farmers/ indigenous/ tribal groups. The flow diagram showing the sampling plan for farmers and key informants is presented in the Figure 3.

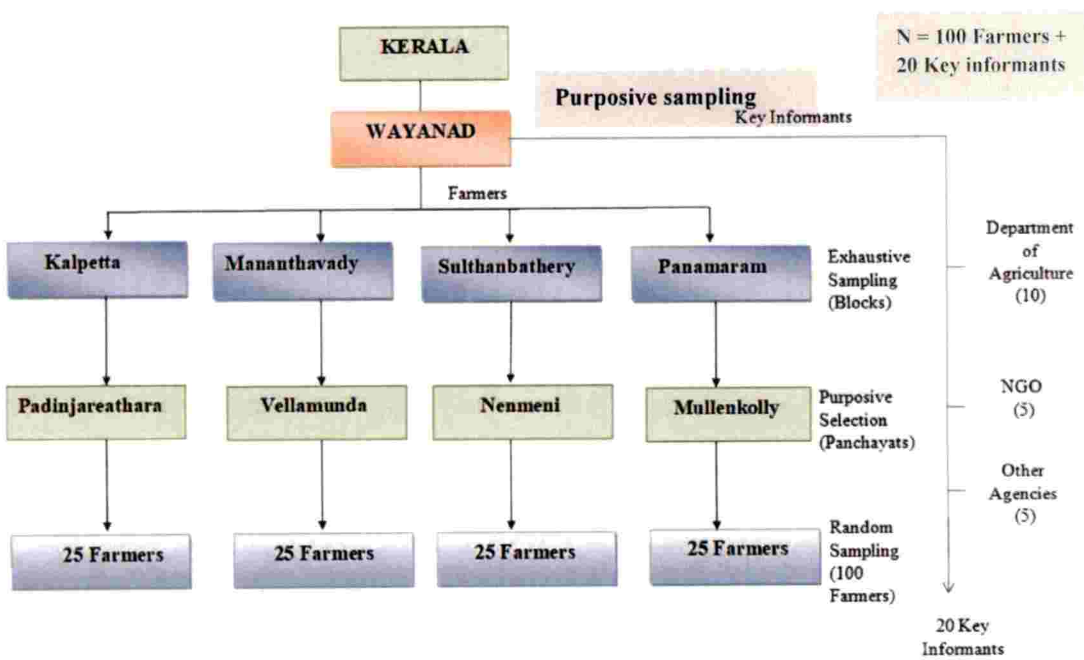

Figure. 3. Sampling plan for farmers and key informants

3. 4 Data collection

The survey of the study area was conducted in the month of December 2017- February, 2018 using standardized measurement instruments developed for the purpose (Plate 1).

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3. 4. 1 Identification and documentation of indigenous weather forecasting practices

Identification and documentation of indigenous weather forecasting practices were done with the help of key informants from different parts of Wayanad. Officials from Department of Agriculture and Farmers Welfare, Non-Governmental Organizations working in the area and members of farmer interest groups working with indigenous/tribal groups were used for identifying the practices. Personal interview method using open-ended schedules was used to collect the data. In order to ensure the collection of meaningful information, participatory tools like Focus Group Discussions (FGD) were also be used involving expert farmers/ key informants and irrelevant and irrational practices were screened off. As much as 35 biotic and 20 abiotic weather forecasting practices were identified and documented as a list for the study.

3. 4. 2 Interview schedule

The main instrument used for collecting data in the study was interview schedule. This contained a list of questions developed, keeping in view of the specific objectives, which helped to collect data on requisite information. The interview schedule was designed in four parts as given below.

a. The first part dealt with information about the location and personal details.
b. The second part covered the abiotic indicators used in weather prediction.
c. The third part covered information on biotic indicators for weather prediction.
d. The fourth part dealt with accessibility and perceived reliability of weather forecast from Department of Agriculture and India Meteorological Department (IMD) by farmers.

The schedule was prepared in simple and clear local language to avoid ambiguity. It was pretested with a sample of 20 in a non-sampling area of Thrissur district. Necessary refinements were made based on the results from pre-tested data. The farmers were personally interviewed by the researcher which enabled to get

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firsthand information. The final interview schedule prepared for the study is presented in Appendix-I.

All the 100 respondents were contacted and rapport was established. The questions and statements were asked in Malayalam, the local language. The questions were put in a conversational manner and responses were transcribed in the schedule itself. In case of responses, which were not clear, rechecking was done. Also secondary sources and published research findings collected through literature search were used to validate the documented ITKs.

3. 5 Operationalization and measurement of variables

Based on the objectives, review of literature, discussions with experts and observations made by the researcher, the following independent and dependent variables were selected for the study.

3. 5. 1 Independent variables

Independent variables pertinent to the study were enlisted based on past researches. Eight variables were selected for the study viz. age, educational status, farming experience, farm size, occupational status, annual income, social participation and cropping pattern.

3. 5. 1. 1 Age

It refers to the number of calendar years completed by the respondents at the time of interview.

3. 5. 1. 2 Educational status

It refers to the number of years spent in formal education and academic record acquired by the respondents at the time of investigation. The farmers were asked directly about their educational qualifications. Educational Status has been divided in to six categories viz. Illiterate, Lower Primary, Upper Primary, High School, Higher Secondary and College level.The method adopted by Dhruthiraj (2016) is used.

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3. 5. 1. 3 Farming experience

It refers to the number of years since a farmer is involved in farming. Based on the number of years it is divided into three categories viz. < 10 years, 10 – 25 years, > 25 years.

3. 5. 1. 4 Farm size

It refers to the area of land (in hector) cultivated by the respondent in a year. Based on farm size, the farmers were grouped into four categories viz. more than 2.0 ha (Large), 1.0 -2.0 ha (Small) and less than 1.0 ha (Marginal).

3. 5. 1. 5 Occupational status

It refers to the nature of work done by the respondents. The scoring procedure followed by Somasundaram (1995) with slight modification was adopted for the study. The respondents were classified into five categories based on the occupational status as given below:

Sl. No	Occupational status	Score
1	Farming alone	5
2	Farming + Agricultural labour	4
3	Farming+ Dairy	3
4	Farming+ Business	2
5	Farming + Professional service	1

3. 5. 1. 6 Annual income

Annual income refers to the total income in rupees generated by the respondent from various vocations/ sources in a year.

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3. 5. 1. 7 Social participation

It refers to the involvement of an individual in formal organizations as a member, as an office bearer or both. The following scoring procedure adopted from Trivedi (1963) was used for the study.

Sl. No	Degree of involvement	Score
1	Member in one organization	1
2	Member in more than one organization	2
3	Office bearer in one organization	3
4	Office bearer in more than one organization	4

3. 5. 1. 8 Cropping pattern

Cropping pattern is the proportion of area under various crops at a point of time as it changes over space and time. The cropping patterns of a region are closely influenced by the geo-climatic, socio-economic, historical and political factors. The cropping pattern is divided into the categories for the study as Rice- Rice, Rice-Vegetables, Inter cropping of Coffee-Arecanut-Pepper, Inter cropping of Coconut-Pepper- Banana, Banana– Tuber crops etc. following scoring procedure is used for the study:

Sl. No	Cropping pattern	Score
1	Rice -Rice	5
2	Rice- Vegetables	4
3	Inter cropping of Coffee–Arecanut– Pepper	3
4	Inter cropping of Coconut- Pepper- Banana	2
5	Banana– Tuber crops	1

3. 5. 2 Dependent variables

3. 5. 2. 1 *Purpose of Use (PU) of indigenous knowledge*

Purpose of use explained whether the farmer uses an indicator for Short Range Forecast (SRF), Medium Range Forecast (MRF) or Long-Range Forecast (LRF). Based on time or duration of forecasting period, the forecasting is divided into (1) short range (valid for 3 days) (2) medium range (valid for 3 to 10 days) and (3) long range (beyond 10 days up to a season or a year).

A scoring pattern was developed for the study based on the logic provided by WMO (2010). Maximun score 3 was given MRF because, this type of forecast was helpful to farmers to plan for various agricultural operations and its accuracy and usefullness were very high. Short range forecast was given score 2, because though the SRF was usefull in weather based agricultural operations, the reaction time to the farmer was too short for preventive measures against adverse weather. The score 1 was given for LRF because its accuracy and usefulness were limited. Non users were accounted as zero, which meant that the particular farmer was unaware of that indicator. The following scoring pattern was used.

Purpose of Use (3-0)	**Score**
MRF	3
SRF	2
LRF	1
Non users	0

3. 5. 2. 1 Extent of Use (EU) of indigenous knowledge

Extent of use of an indigenous knowledge was measured in terms of regularity of use and time of use. Regularity of use was operationalized to have three dimensions – regular use, once in a while and heard but not practicing with scores three, two and one respectively. Time of use was also divided into three dimensions– throughout the year, seasonal and at particular time with scores three, two and one respectively. The scores assigned followed the pattern given below:

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Extent of use (6 – 2)			
Regularity of use	**Score**	**Time of use**	**Score**
Regular use	3	Throughout the year	3
Occasional use	2	Seasonal	2
Heard but seldom used	1	Sporadically	1

3. 5. 2. 3 Perceived Reliability (PR) of indigenous knowledge

Reliability was conceptualized as the trustworthiness of an indicator in giving the desired outcome in the local situation as perceived by the farmer. The reliability was measured in three measures viz. Reliable, sometimes reliable and seldom reliable. The following scoring procedure is adopted in the study.

Perceived reliability (3-1)	Score
Reliable	3
Sometimes reliable	2
Seldom reliable	1

3.5.2.4 Accessibility and perceived reliability of weather forecast from agricultural department and IMD as conceived by farmers

Accessibility is the extent to which a farmer gets weather forecast information from agricultural department and IMD at the time it is needed. Since agro-met information services are still in the early stages, it has to be checked whether the selected panchayats were accessible to agro-met information services from agricultural department. This information was identified by informal discussions with the service provider staff.

For checking the accessibility of the weather forecast information, the farmers were asked about their perception regarding the accessibility of the weather forecast information in the selected study area. Accessibility of weather forecast was theorized in two dimensions – accessible and inaccessible. Farmers' accessibility to weather forecast information, weather broadcast of television (TV), radio, newspapers, mobile phones and agricultural extension officers.

Reliability of weather forecast is the trustworthiness of weather forecast information in giving the desired outcome in the local situation as perceived by the farmer. The following scoring procedure was used in the study.

Reliability of weather forecast	Score
Reliable	3
Somehow reliable	2
Not reliable	1

3. 6 Validation of documented indigenous practices

Validation was operationalized as the process of checking the quality of recorded ITKs in terms of its logical and factual exactness based on

1. Farmers' perception - Use Validation Scores (UVS)
2. Published research findings/ theories-research citations

3. 6. 1 Validation of the documented ITKs through farmer participatory processes using Use Validity Score (UVS)

Documented ITKs were validated through farmer participatory process using Use Validity Score (UVS). Use validity of a particular ITK was measured on three dimensions viz. purpose of use (PU), extent of use (EU) and perceived reliability (PR). The subclassification and its scores assigned are diagramatically represented in the Figure 4.

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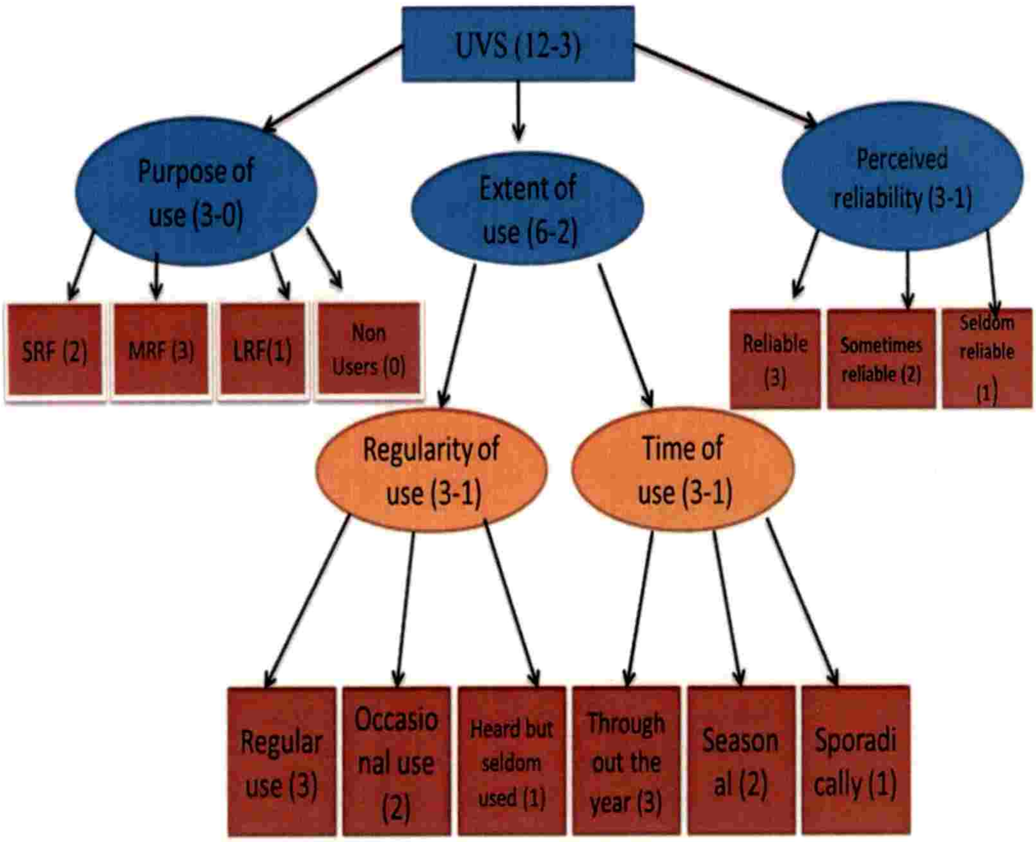

Figure. 4. Flow diagram showing scores assigned to purpose of use (PU), extent of use (EU) and perceived reliability (PR) used to measure UVS

A score sheet was prepared using the above scoring pattern for each individual farmer. The Use Validity Score (UVS) was developed as sum of product of each component score (*PU score, EU score, PR score*) and their respective weightage (*Wpu, Weu, Wpr*) as given in equation (1).

UVS of a farmer = (Wpu * PUscore) +(Weu * EUscore) + (Wpr * PRscore)

----------- **Eq. (1)**

Where,

***Wpu** – Weightage of PU*

***Weu** – Weightage of EU*

***Wpr**– Weightage of PR*

***PUscore**– Purpose of use score*

***EUscore** – Extent of use score*

***PRscore** – Perceived reliability score*

The above score was calculated for each farmer and the average of the scores for the sample was used as the Use Validity Score of a particular indicator. Ranking of ITKs was done based on Use Validity Score.

The weightage for each component was calculated based on the procedure developed by Rao (1987). It followed the logic that, the variables which were highly correlated with others should have more weightage. The formulae used to calculate the weights for PU, EU and PR are given as equation (2), (3) and (4) respectively.

$$W_{pu} = \frac{r_{pu.eu} + r_{pu.pr}}{2\,(r_{pu.eu} + r_{pu.pr} + r_{eu.pr})} \quad \text{----------- Eq. (2)}$$

$$W_{eu} = \frac{r_{pu.eu} + r_{eu.pr}}{2\,(r_{pu.eu} + r_{pu.pr} + r_{eu.pr})} \quad \text{----------- Eq. (3)}$$

$$W_{pr} = \frac{r_{pu.pr} + r_{eu.pr}}{2\,(r_{pu.eu} + r_{pu.pr} + r_{eu.pr})} \quad \text{----------- Eq. (4)}$$

Where,

Wpu *– Weightage of PU* — $r_{pu.eu}$ – *Inter correlation between pu and eu*

Weu *– Weightage of EU* — $r_{pu.pr}$ – *Inter correlation between pu and pr*

Wpr *– Weightage of PR* — $r_{eu.pr}$ – *Inter correlation between eu and pr*

The inter correlation between PU, EU & PR was worked out using Spearman Rank Correlation in Statistical Package for the Social Sciences (SPSS version 16.0).

The Mean ($\bar{x}$) and Standard deviation (S.D) of UVS of all indicators were used to affirm the popularity classification of indigenous indicators for weather prediction.

Classification of indigenous indicators used the mean and standard deviation as given below:

Classification	Criteria
High	More than ($\bar{x}$ + S.D)
Medium	Between($\bar{x}$ + S.D)to ($\bar{x}$ - S.D)
Low	Less than ($\bar{x}$ - S.D)

3. 6. 2 Validation of the documented ITKs through published research findings/ theories-research citations

Validation of the documented ITKs was also done through thematic content analysis with information collected from the secondary sources like journals, scientific reports, relevant literature thesis and books. Based on scientific proof, the ITKs were classified into

a) Scientifically validated indicators

b) Experientially validated indicators

Scientifically validated indicators are explained with the existing theory and findings from scientific reports of research. Experientially validated indicators are those with no feasible explanation in the existing scientific frame work but were popular among farmers and needed further research.

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3.7 Statistical tools used for the study

For the purpose of statistical analysis to fulfill the set objectives, the following statistical tests were used.

1. **Frequency and percentage**

   Frequency analysis gives the number of occurrences of each response selected by the respondents. Percentage is a number expressed as it is the part of a total which is hundred.

2. **Arithmetic mean ($\overline{x}$)**

   It is defined as the sum of all values of the observations divided by the total number of observations.

3. **Standard deviation (SD)**

   The standard deviation measures variability and consistency of the sample or population.

4. Spearman's Rank Order Correlation

Spearman Rank Correlation is a non-parametric test that is used to measure the degree of association between two variables. The inter correlation between PU, EU and PR was found out using SPSS version 16.0. This is further used for the calculation of weightage of purpose of use (Wpu), extent of use (Weu) and perceived reliability (Wpr).

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Plate 1. Student researcher with the respondents during data collection

RESULT & DISCUSSION

CHAPTER 4

RESULT AND DISCUSSION

The findings of the study in line with the objectives set forth are presented here, with appropriate discussions, under the following titles.

4.1 Distribution of respondents according to their profile characteristics

4.2 Documentation of indigenous weather forecasting indicators

4.3 Validation of documented ITKs in weather prediction

4.4 Scope of validated ITKs in local crop weather forecast based on farmer perception

4.5 Accessibility and perceived reliability of weather forecast from agricultural department and IMD by farmers

4. 1 Distribution of respondents according to their profile characteristics

Results of the profile of farmers who used ITKs on selected socio-economic variables are presented. An attempt was made to evaluate the results based on the existing theories on the socio-economic characters of ITK users. The results related to personal and socio-economic characteristics of farmers are depicted in Table 1.

4. 1. 1 Age

Average age of farmers was above 61 years with 57 per cent above and 43 per cent below the mean score. This along with the range (27 – 87) was used to categorize the farmers into young, middle and old aged groups as given in Table 1. The detailed analysis found that the majority (63%) of the farmers belonged to old age category, which validates the theoretical basis for indigenous knowledege. Farmers belonging to the age group of less than 30 years were only 2 per cent of the total respondents. This may be due to the fact that, the younger generation is not taking up agriculture as their occupation and even those involved were more

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inclined to formal scientific metereological sources. The results obtained are in accordance with the results of Sasidharan (2015).

4. 1. 2 Education

Average education of farmers was around 3.6, which was around the value for high school education. This indicated that, the majority of respondents belonged to upper primary (18%) and high school (51%) educational categories. Illiterate and lower primary covered only 3 per cent and 16 per cent respectively. Only 8 per cent and 4 per cent had educated up to higher secondary and college level. Most of the literature on ITK showed low education level for farmers interested in ITKs (Msuya, 2007). However, the variant results can be substantiated as an influence of the high literacy rate of Kerala. Moreover, limited access to the formal sources of meteorological information in this climatic hot spot might have driven the better educated farmers also to rely on ITKs.

4. 1. 3 Farm size

Results from Table 1. indicated that majority of the farmers (56%) had farm size above 1.50 ha which came under small holding size and is well above the state average farm size of 0.22 ha (GOK, 2016). This can be attributed to the geographical peculiarity of the state, where majority of farmers are settlers who had forest lands legalised through government permits. Marginal farmers with farm size below 1 ha constituted 44 per cent of respondents. The range was between 0.14 ha and 3.84 ha which indicated the wide variation that existed in farm size among the farmers.

4. 1. 4 Farming experience

Results in Table 1. revealed that, the farmers had an average 28 years of experience in farming. Majority (73%) of the respondents was having more than 25 years of experience followed by 10–25 years experience (21%) and less than 10 years (6%) experience. Conceptually indigenous knowledge was associated with people's accumulated experience in dealing with contextual problems in various aspects of life (Wang, 1988) and more experience meant more knowledge about ITKs which validates the results.

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Table 1. Profile characteristics of the respondents N=100

Variable	Category (score)	Frequency	Mean	Range
Age (years)	Young (upto 30 years)	2	61.27	27 - 87
	Middle (31 - 50 years)	35		
	Old (above 50 years)	63		
Education (years)	Illiterate (1)	3	3.60	1- 6
	Lower Primary (2)	16		
	Upper Primary (3)	18		
	High School (4)	51		
	Higher Secondary (5)	8		
	College level (6)	4		
Farm size (ha)	Marginal (<1.0 ha)	29	1.50	0.14 - 3.84
	Small (1.0-2.0ha)	51		
	Large (>2.0 ha)	20		
Farming experience (years)	Less than 10 years	6	28	2 - 61
	10 – 25 years	21		
	More than 25 years	73		
Occupational status	Farming alone (5)	24	3.49	1- 5
	Farming + Agricultural labour (4)	28		
	Farming+ Dairy (3)	27		
	Farming+ business (2)	15		
	Farming + professional service (1)	6		
Annual income (Rs.)	Less than 2 lakh	38	2.66	0.30- 15.5
	2 to 5 lakh	49		
	More than 5 lakh	13		
Social participation	Member in one organization (1)	49	1.66	1-4
	Member in more than one organization (2)	39		
	Office bearer in one organization (3)	9		
	Office bearer in more than one organization (4)	3		
Cropping pattern	Rice- Rice (5)	18	3.18	1 - 5
	Rice–Vegetables (4)	28		
	Coffee–Arecanut– Pepper (3)	21		
	Coconut- Pepper- Banana (2)	20		
	Banana – Tuber crops(1)	13		

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4. 1. 5 Occupational status

Important inference from Table 1. was that, the most popular occupation of the respondents was farming along with diary as evident from the mean score of 3.49. Farmers with dairy as an additional component constituted 27 per cent of the respondents. It had the advantage of providing income for almost the whole year including agricultural off seasons. Agricultural labourers who had farming as a subsidiary vocation comprised of 28 per cent of the respondents. Farming alone was the occupation of about 24 per cent of the respondents which was followed by 15 per cent who had farming along with business and for 6 per cent farming was a source of additional income along with professional job. It is evident from the results that, for all categories, agriculture formed an important source of income and as such vagaries of climate effected their livelihoods. Therefore, they relied on ITKs as a strategy to reduce the related uncertainties.

4. 1. 6 Annual income

The average annual income of farmers was Rs.2.66 lakhs with 59 per cent above and 41 per cent below the mean score. The annual income that ranged between 0.30 and15.5 lakhs. The wide variation was the result of high diversity in the crops raised which varied from food crops like rice and vegetables to plantation crops like pepper, tea and coffee. Moreover, the risk involved in cultivation was also high which explained the reliance on ITKs.

4. 1. 7 Social participation

Results presented in Table 1. indicated that, the average social participation score of farmers was 1.66, which indicated that, the farmers had membership in more than one organization. About 49 per cent of respondents were the members in at least one organization and 39 per cent had membership in more than one organization. Only 9 per cent and 3 per cent reported to serve as office bearers in one and more than one organization respectively. The results showed high social participation trend among farmers and this networking would have helped in having a knowledge of the traditional methods of weather prediction using ITKs. However, the result was against the findings of Kailash (2010).

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4. 1. 8 Cropping pattern

The results from Table 1. showed that majority (28%) of the farmers practiced rice-vegetables cropping system followed by inter crop of coffee-arecanut-pepper (21%), rice- pepper- banana (20%), rice- rice (18%) and banana-tuber crops (13%). The mean score of 3.18 revealed coffee- arecanut-pepper cropping system was the predominant type. Though rice related cropping patterns are the traditional systems in Wayanad, of late they have been replaced by coffee based commercial systems. However, all these crops need climate resilient strategies and close observation of changes in weather patterns forms a prerequisite for successful cultivation. This explains the high dependence of these farmers on ITKs.

4. 2 Documentation of indigenous weather forecasting indicators

The various abiotic and biotic indicators related to weather prediction identified in the study were documented and validated for better understanding. Based on the type, recorded ITKs were classified as abiotic and biotic indicators and are presented under the respective heads below.

4. 2. 1 Abiotic indicators for weather prediction

Study delineated twenty abiotic indicators related to weather prediction from the area. These indicators are based on characteristics of clouds, sky, moon, wind, rainbow, fog, thunder and lightning, temperature, water levels in open water bodies and rainfall and how its variations are used for predicting weather were explained. Different abiotic indicators related weather predictions documented with the help of key informants are presented in Table 2 (plate 2 a. & 2 b.).

Most of the indicators recorded were supported by documentation made in similar studies conducted in other parts of the world. Indication of heavy rainfall from dark rolling clouds along with cool breeze was in conformity with the findings of Rengalakshmi (2008), Shankar *et al.* (2008), Sivanarayana and Vani (2011) and Chinlampianga (2011).

Association of widespread cloud covered with on and off light showers over several hours, clouds with vertical development associated with thunderstorm, lightning and heavy rainfall, rainbow in the western sky and halo around the moon as indicators of good rainfall were in line with the findings of Shankar *et al.* (2008). The relation between cool breezes along with moisture and rainfall was also repeated by Varshneya *et al.* (2009). Thunder and lightning as indicators of upcoming rain were in line with the findings of Rengalakshmi (2008). Unusual increased temperature during day and night as indication of the onset of rain was in accordance with the findings of Okonya *et al.* (2013) and Nganzi (2014). Red clouds and sky were associated with no rainfall and was in conformity with the findings of Agricultural Meteorology Department of KAU (2015).

Table 2. List of abiotic indicators used in weather prediction and related predictions

Sl. No.	Indigenous Technical Knowledge	Weather prediction
1. Indicators related to clouds		
1	Dark rolling clouds along with cool breeze	Rainfall
2	Widespread cloud (low clouds) cover	Long intermittent light showers
3	Clouds with vertical development	Thunderstorm, lighting and heavy rainfall
4	Red clouds	No rainfall
2. Indicators related to moon		
1	Halo around the moon	Good rainfall
2	Clear moon and stars	No rainfall
3. Indicators related to wind		
1	Cool breeze along with moisture	Rainfall
2	Warm breeze in February- March	Rainfall
3	Whirlwinds or dust devils	Onset of dry seasons/ No rainfall
4. Indicators related to sky		
1	Clear blue sky	No rainfall
2	Red sky	No rainfall
5. Indicators related to rainbow		
1	Rainbow in the western sky	Rainfall
2	Rainbow in the eastern sky	No rainfall
6. Indicators related to fog		
1	Dense fog in early morning	No rainfall
7. Indicators related to thunder and lightning		
1	Thunder and lightning	Rainfall
2	Thunderstorm in April- May	Hailstones and heavy rainfall
8. Indicators related to temperature		
1	Unusual increased day and night temperature	Rainfall
2	Drop in temperature at night/cool nights	Onset of dry season/ no rain
9. Indicators related to water level and rainfall		
1	Reduction in water level in swamps and lagoons and *Kenies* (small well like structures)	Drought
2	Occurrence of rain in presence of sunshine	Absence of rain in near future

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Nganzi (2014), Sarkar *et al.* (2015) and Chinlampianga (2011) reported clear moon, stars and sky as associated with no rainfall. Temperature drop at night and whirlwinds are used to indicate onset of dry season which was in line with the findings of Nganzi (2014). Rainbow in the east direction and appearance of fog in the morning was a sign of no rain, these findings corroborate with the findings reported by Anandaraja (2008). Drop in water level in *Kenis* as sign of impending drought was similar to the reports by Nair (2016) and Padre (2013).

Supplementary evidences reported for most of the indicators at the national and global levels implied its relevance and presence in diverse agro-ecosystems across the globe. Therefore, the most significant inference that can be derived from the results was that, there exists a general agreement among diverse users with respect to the use of many of the documented abiotic factors.

4. 2. 1. 1 Distribution of abiotic weather forecast indicators in relation to predicted weather

The distribution of different weather forecast indicators in relation to the weather is represented in Table 3 and its percentage distribution is given in Figure 5.

Table 3: Distribution of abiotic weather forecast indicators in relation to weather

Sl. No.	Abiotic factor	Predicted weather & No. of indicators			Total
		Rainfall	Dry season/ No rainfall	Drought	
		No. of indicators	No. of indicators	No. of indicators	
1	Cloud	3	1	0	4
2	Moon	1	1	0	2
3	Wind	2	1	0	3
4	Sky	0	2	0	2
5	Rainbow	1	1	0	2
6	Thunder and Lightning	2	0	0	2
7	Temperature	1	1	0	2
8	Fog	0	1	0	1
9	Water level / Rainfall	0	1	1	2
Total		**10**	**9**	**1**	**20**

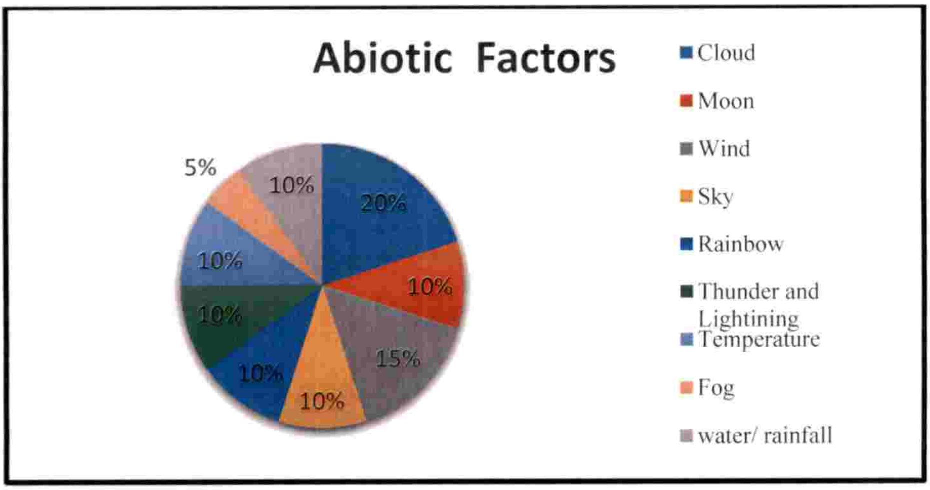

Figure. 5. Percentage distribution of abiotic weather forecast indicators

The indicators related to clouds accounted 20 per cent and were associated with farmers' observations on cloud color, movement and pattern. This was followed by indicators related to wind at 15 per cent of the documented indicators. The percentage share of indicators related to moon, sky, rainbow, thunder and lightning, temperature, water and rainfall were 10 per cent each. Only 5 per cent of the indicators were related to fog, because Wayanad is a high-altitude district and fog is a common phenomenon throughout the year, so farmers are least concerned about that particular indicator.

Out of the twenty indicators related to nine abiotic factors, maximum number (10) of indicators were used in the prediction of rain followed by nine indicators that were associated with the prediction of the onset of dry season/ no rainfall. There was only one indicator that was used to predict drought or water scarcity. The high reliance on abiotic indicators for rainfall prediction can be attributed to the rainfed nature of cultivation followed by the farmers of the area and their limited access to location specific rainfall forecasts from conventional meteorological sources. This necessitated the farmers to depend on their traditional knowledge of rainfall prediction so that, the uncertainties related to weather sensitive farm decisions can be overcome.

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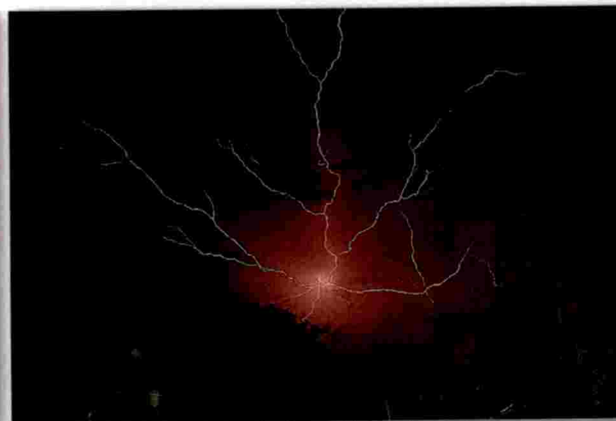
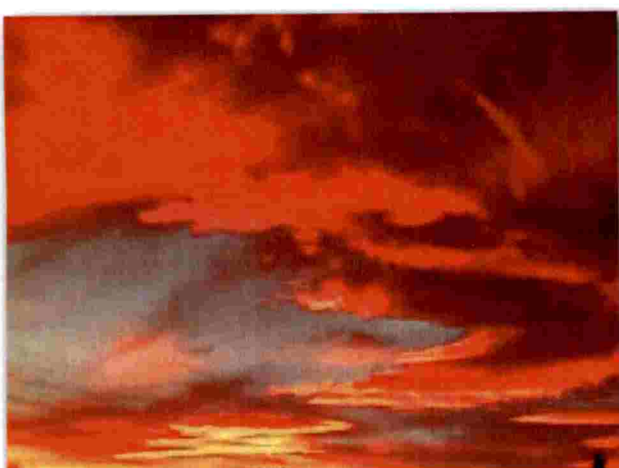
Clear blue sky indicates no rainfall

Dark rolling clouds indicate rainfall

Clouds with vertical development indicate thunderstorm, lightning and heavy rainfall



Lightning indicates rainfall



Red clouds indicate no rainfall

Wide spread cloud cover indicates intermittent rainfall

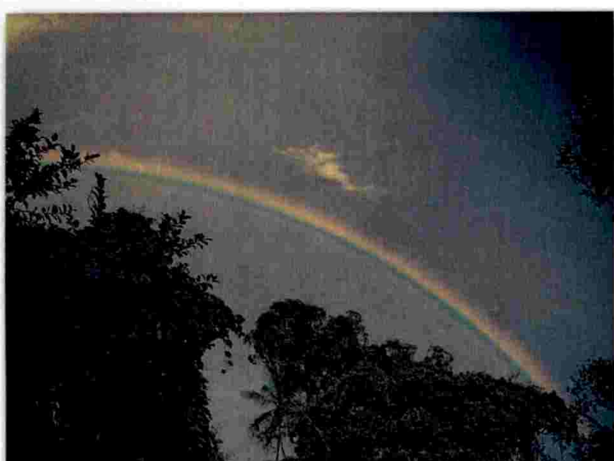
Plate 2 a. Abiotic indicators for weather prediction

Clear moon indicates no rainfall

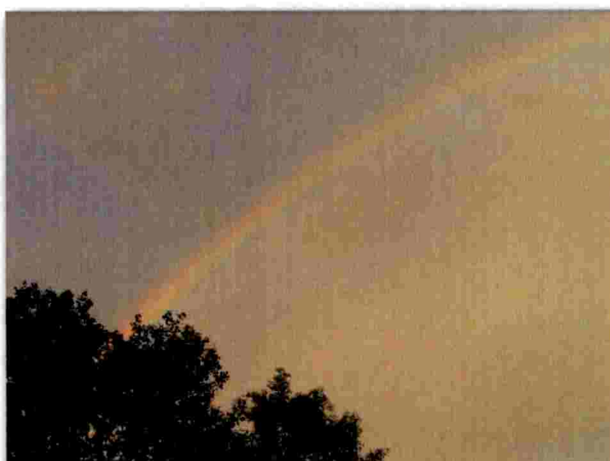
Red sky indicates no rainfall

Dense fog in the early morning indicates no rainfall

Halo around the moon indicates rainfall



Rainbow in the eastern sky indicates no rainfall



Rainbow in the western sky indicates rainfall

Plate 2 b. Abiotic indicators for weather prediction

4. 2. 2 Biotic indicators for weather prediction

Thirty-five indigenous practices related to biotic indicators used for weather prediction were identified through interviews with the key informants. These indicators were based on the phenology of certain plants and behavior of certain animals in response to changes in atmospheric conditions. Accordingly, they were categorized as plant-based indicators and animal-based indicators.

4. 2. 2. 1 Plant based biotic indicators in weather prediction

Results related to plant-based indicators used by farmers of the study area are presented in Table 4. It revealed the presence of seven weather prediction indicators of which majority (57%) was related to rainfall prediction and 43 per cent of the indicators were associated with the prediction of dry periods. This again reiterates the significance of rainfall related forecasts for farmers and above all, other factors that influence crop production (Plates 3 a. & 3 b.).

4. 2. 2. 2 Animal based biotic indicators in weather prediction

Different biotic indicators related weather predictions based on animals were grouped into invertebrates (plates 4 a., 4 b., 4 c.) and vertebrates (plate 5.) category and are presented as Table 5 (a) and 5(b) respectively. There are 13 indicators reported from invertebrate category and 15 from the vertebrate group. Insects dominated in the invertebrate category and within the vertebrate category were the avians. In the invertebrate category, 69.2 per cent of the indicators were related to rainfall prediction and 30.8 per cent of the indicators were related to prediction of dry season. Same trend was seen in vertebrates, 73.3 per cent of the indicators were related to rainfall prediction and only 26.7 per cent of the indicators were related to prediction of dry seasons/ drought. This again conforms the significance of rainfall related forecasts for farmers and above all, other factors that influence crop production.

Table 4. List of plant indicators used in weather prediction and related predictions

Sl. No.	Indigenous Technical Knowledge	Weather prediction
I. Indicators related to plants		
1	Heavy flowering of South Indian Plum (Njarapazham: *Syzygium caryophyllatum)*	Good rainfall
2	Fully developed three seeds in the fruits of Flame of Forest (Chamata: *Butea monosperma)*	Good rainfall with uniform distribution throughout the season
3	Softening of stored flowers of Illipe butter tree (Aattuelippa: *Madhuka nerifolia)*	Upcoming rain
4	Softening of stored tamarind (Puli: *Tamarindus indica)*	Upcoming rain
5	Heavy flowering of mango tree (*Mangifera sp.)*	Drought
6	Flowering of night blooming jasmine (Andhimulla: *Cestrum nocturnum)*	No rainfall / Dry season
7	Early flowering of Golden shower tree (Kanikonna: *Cassia fistula)*	Increasing temperature

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Table 5 (a). List of invertebrate animal indicators used in weather prediction and related predictions

Indigenous Technical Knowledge		Weather prediction
A. Invertebrates		
1.Indicators related to annelids		
1	Earthworms (*Lumbricus terrestris)* come out of the ground in rainy season	Ensure good rain in the particular day
2. Indicators related to insects		
1	Dragon fly (*Odonata sp.*)flying low in groups	Upcoming rain
2	Swarming of winged termites/ black rainfly (*Reticulitermes sp.*) in the evening	Upcoming rain
3	Ants (*Componotus sp.*) transport eggs to safer place	Upcoming rain
4	Cicada (*Cicadoidea sp.*)singing in groups	Upcoming rain
5	Biting nature of housefly (*Musca domestica*)	Upcoming rain
6	Honey bee (*Apiscerana indica*) hide their honey comb and reduced bee activity	Upcoming rain
7	Spider makes thicker vertical webs relative to earth	Upcoming rain / Onset of rainy season
8	Crabs makes sloppy holes in soil	Good rainfall
9	Appearance of large number of grasshoppers	Upcoming rain
10	Presence of Army worms (*Spodoptera sp.)* in large numbers in paddy	No Rainfall
11	Termites (*Globitermes sulphureus*) developing new mounts	Rainfall
12	Butterflies (white colour) are seen in large numbers	No rainfall

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Most of the biotic indicators recognized were supported by documentation made in similar studies conducted in other parts of the world. Indication of potential drought season by profuse flowering of mango tree was in conformity with the findings of Joshua *et al.* (2011). Before rainfall, stored flowers of *Aattu elippa* getting softened was earlier documented by Kumari (2008).

Sivanarayana (1993) reported that, the development of all the three seeds in the fruits of *Butea monosperma* indicated uniform distribution of rainfall throughout the season.

Prior to rain, dragonfly flying down to earth was in conformity with the findings of Acharya (2011) and Agricultural Meteorology Department, KAU (2014).

Frog croaking near marshy areas, chickens staying under shade at noon time and seeming to like taking bath with soil and bees hiding their honey comb were signs of rainfall. These findings are corroborated with the findings reported by Acharya (2011).

The present finding of forecasting the onset and cessation of monsoon by observing the orientation of spider web was in conformity with the findings of ICAR (2004). Crabs making sloppy holes in soil associated with upcoming rain is in conformity with the findings of Agricultural Meteorology Department, KAU (2015).

The previous researchers Golakia (1992) and Acharya (2011) documented that peacocks crying frequently were associated with upcoming rain. Abundance of butterflies during the farming season and presence of army worms in the field indicated imminent mid-season drought and possible famine reported by UNEP (2008). Cicada singing in groups signifying imminent rainfall was in conformity with the findings of Mugabe *et al.* (2010), Joshua *et al.* (2011) and Risiro *et al.* (2012). From these observations, it was clear that, the documented weather prediction indicators are commonly practiced by farmers in different parts of the world.

Table 5(b). List of vertebrate animal indicators used in weather prediction and related predictions

B. Vertebrates		
1. Indicator related to fish		
1	Emergence of fish swimming near the surface of pond	Upcoming rain
2. Indicator related to amphibians		
1	Frogs (*Rana hexadactyla*) croaking near swampy areas in groups	Upcoming rain
3. Indicator related to reptiles		
1	Large number of snakes	Good rainfall
4. Indicators related to avians		
1	Jungle owlet (*Glaucidium radiatum*) make special sounds	Upcoming rain
2	Grey wagtail (Mazhakunni / Kunnikili flies/ Nilamkulukki pakshi: *Motacilla cinerea*) fly down to the earth in groups	Upcoming rain
3	Eagle (Chembarundhu: *Halias turindus*) make special sounds and flies low	Upcoming rain
4	Unusual chirping of Hill myna (*Gracula religiosa*) and aggressive behaviour	Upcoming rain
5	Greater Coucal (Uppan/ chamboth: *Centropus sinensis*) making special sounds	Upcoming rain
6	Peacock (*Pavo cristatus*) making special sounds and rhythmic movements	Upcoming rain
7	Indian grey hornbill (*Ocyceros birostris*) making noise	Upcoming rain
8	Chicken (*Gallus gallus*) staying under shade and bathing in dust	Upcoming rain
9	Crows (*Corvus splendens*) crying during the night	Drought
5. Indicators related to mammals		
1	Jumping of cattle (*Bos taurus*)	Upcoming rain
2	Unusual barking and restlessness of street dogs (*Canis familiyaris*)	Rain
3	Malabar giant squirrel (Malayannan: *Ratufa indica*) seen in large numbers	No rainfall

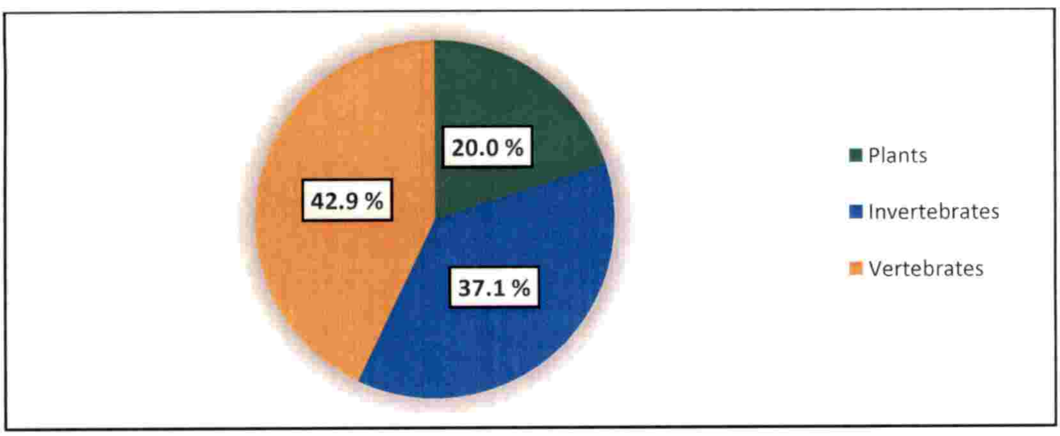
4. 2. 2. 3 Distribution of weather forecast indicators in relation to various biotic factors to predicted weather

The distribution of different weather forecast indicators in relation to various biotic factors is represented in Table 6, and its percentage distribution is given in Figure 6.

Table 6. Distribution of different weather forecast indicators in relation to various biotic factors for predicting weather

Sl. No	Biotic factor	Predicted weather & No. of indicators			Total
		Rainfall	Dry season/ No rainfall	Drought	
		No. of indicators	No. of indicators	No. of indicators	
1	Plants	4	1	2	7
2	Invertebrates	11	2	0	13
3	Vertebrates	13	1	1	15
Total		**28**	**4**	**3**	**35**

Figure. 6. Percentage distribution of biotic weather forecast indicators in relation to predicted weather



Out of the thirty-five biotic indicators, majority (42.9 %) of indicators was associated with vertebrates including fishes, amphibians, reptilians, avians and mammals, 37.1 per cent indicators were related to invertebrates which included the insects and annelids. Only 20 per cent of the indicators were related to the flowering and fruiting penology of plants.

The data represented in Table 6 revealed that, out of the thirty-five biotic indicators, twenty-eight were associated with the prediction of rainfall, four indicators were related to the prediction of dry season and no rainfall and three indicators were associated with the prediction of drought. This again confirms the importance of rainfall related predictions for farmers than all the other factors that influence the crop production.

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Heavy flowering of South Indian Plum indicates good rainfall

Fully developed seed in the fruits of Flame of Forest indicates good rainfall and uniform distribution throughout the year

Flowering of Night Blooming Jasmine indicates onset of dry season

Softening of stored flowers of Illipe Butter Tree indicates upcoming rain

Softening of stored tamarind indicates upcoming rain

Plate 3 a. Biotic Indicators - Plant indicators used in weather prediction

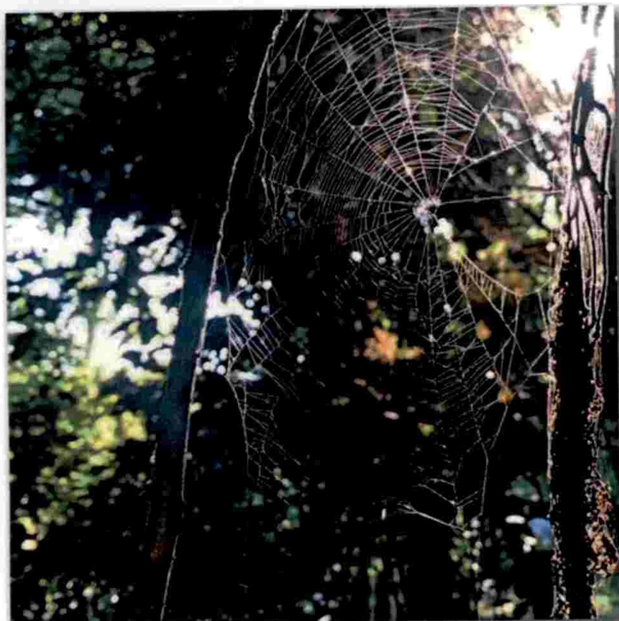
Heavy flowering of mango tree indicates drought

Early flowering of Golden Shower Tree indicates increasing temperature

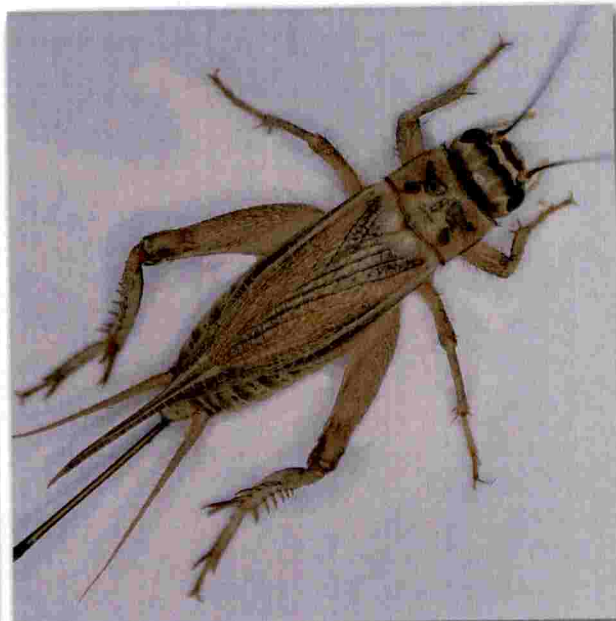
Plate 3 b. Biotic Indicators - Plant indicators used in weather prediction

Dragon fly flying low in groups indicates upcoming rain

Earth worm coming out of the ground in the rainy season indicates good rain on the day



Spider making thicker vertical webs relative to earth indicates onset of rainy season



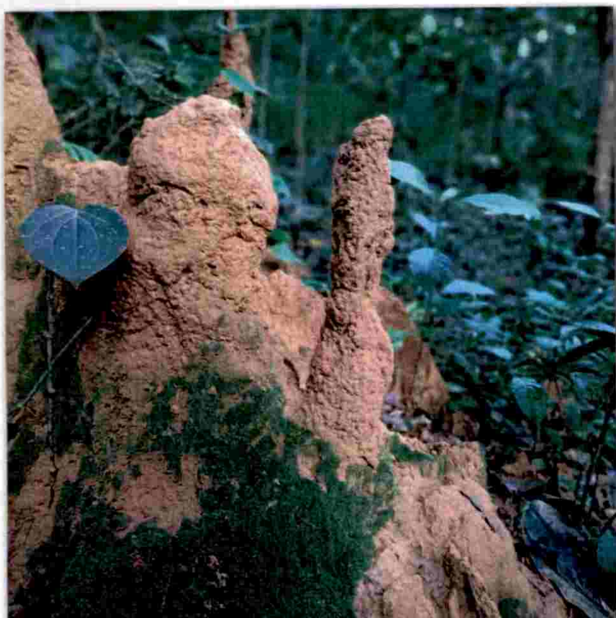
Cicada singing in groups indicates upcoming rain

Swarming of winged termite in the evening indicates upcoming rain

Plate 4 a. Biotic indicators - Invertebrate animal indicators used in weather prediction

Crabs making sloppy holes in the soil indicate good rainfall

Appearance of large number of grasshoppers indicates upcoming rain



Termites developing new mounts indicate rainfall

Butterflies (white colour) seen in large numbers indicate no rainfall

Ants transporting eggs into safer place indicate upcoming rain

Plate 4 b. Biotic indicators - Invertebrate animal indicators used in weather prediction

Presence of Army worms in large numbers in paddy indicate no rainfall

Plate 4 c. Biotic indicators - Invertebrate animal indicators used in weather prediction

Frogs croaking near swampy areas in groups indicate upcoming rainfall

Unusual chirping of Hill myna indicates upcoming rainfall

Grey wagtail flying down to the earth in groups indicates upcoming rain

Greater Coucal making special sounds indicate upcoming rainfall

Chicken staying under shade and bathing in dust indicate upcoming rainfall

Indian grey hornbill making special noise indicates upcoming rainfall

Plate 5. Biotic Indicators - Vertebrate animal indicators used in weather prediction

4. 3 Validation of documented ITKs in weather prediction

Validation is the process of checking the quality of recorded ITKs in terms of its logical and factual exactness as perceived by users or scientific studies. In the study documented, ITKs were validated using Use Validation Scores (UVS) based on farmers' perception and also a scientific validation using corroborative published research findings and the results are presented under the respective heads.

4. 3. 1 Validation of abiotic indicators based on farmers' perception

Use Validity Score (UVS) was used in the validation of documented abiotic indicators by farmers. Purpose of use, extent of use (measured in terms of regularity and time of use) and perceived reliability as reported by farmers were used as measures of use validity. Though the farmers were aware of the indicators, some of them were not used by them for weather prediction and had only a vague understanding of how they performed. However, these indicators were also included in the calculation of UVS as they expressed some awareness though not confident about its functioning.

4. 3. 1. 1 Purpose of use of abiotic indicators based on farmers' perception

Purpose of use explained whether the farmer used an indicator for Short Range Forecast (SRF), Medium Range Forecast (MRF) or Long Range Forecast (LRF). Purpose for which indigenous abiotic indicators were used by above 50 per cent of the respondents is given in Table 7.

The results from Table 7 showed that nine indicators were used for SRF and five indicators for MRF and two indicators for LRF by majority of the farmers. It is evident from the table that, the indicator codes A, B, D, I, L, N, O, C, and F denoted the SRF indicators. These codes represented dark rolling clouds with cool breeze (66%), thunder and lightning (66%), cool breeze along with moisture (51%), thunderstorm in April- May (48%), rainbow in the western sky (36%), warm breeze in February- March (42%) and clouds with vertical development (33%) respectively. These were reported to be used for short range forecasts of rainfall.

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It is also evident from Table 7 that, indicator codes C and F associated with clear blue sky (57%) and dense fog in early morning (39%) respectively, were used to predict absence of rainfall in the short range. Similar findings were also reported by Anandaraja *et al.* (2008).

Indicators used in MRF were represented by codes E, J, K, M and P of Table 7. These codes corresponded to clear stars and clear moon at night (43%), red sky (39%), unusual increased temperature during day and night (26%), red clouds in the evening (27%) and halo around the moon (27%) respectively. Of these, MRF indicators, K and P were related to prediction of rains, whereas E, J and M predicted dry spell (no rain). The findings are in line with the results of Rengalakshmi (2008) and Shankar *et al.* (2008).

Indigenous abiotic indicators for LRF of weather were comparatively fewer in number as evident from Table 7. The indicator codes G and H were used by majority of the respondents for LRF. These codes symbolized reduction in water levels in swarms, lagoons and *Kenies* (45%) and drop in temperature at night (40%) respectively. All these were clear indicators for the onset dry season or no rainfall. The results are similar to those obtained by Nganzi (2014).

Indigenous abiotic indicators for weather prediction which were used by less than 50 per cent of farmers are presented in Table 8. Results from the table showed that, two abiotic indicators used for SRF were Q and R, whereas S was associated with MRF and T with LRF. Rainbow in the east direction (25%) and widespread cloud cover with light intermittent showers over several hours (18%) represented the SRF indicators used for prediction of dry spell and the onset rains respectively. Whirlwinds or dust devils (S) were used in MRF by 9 per cent farmers as clear indication of the onset of dry seasons. Occurrence of rain in presence of sunshine that indicated absence of rain in near future (T) was used in LRF by only 7 per cent of farmers. Likewise, Nganzi (2014) also found similar findings.

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Table 7. Purpose of use of indigenous abiotic indicators for weather prediction with high adoption among farmers N=100

Sl. No.	Indicator	Indicator Code	SRF	MRF	LRF	Non users
			%	%	%	%
1	Dark rolling clouds along with cool breeze indicates heavy rainfall	A	66	21	04	09
2	Thunder and lightning indicate upcoming rain	B	66	17	10	07
3	Clear blue sky indicates no rainfall	C	57	21	17	05
4	Cool breeze along with moisture indicates rainfall	D	51	32	01	16
5	Clear moon and clear stars indicate no rainfall	E	32	43	19	06
6	Dense fog in early morning indicates no rainfall	F	39	23	07	31
7	Reduction in water level in swamps, lagoons and *Kenies* indicates drought	G	09	22	45	24
8	Drop in temperature at night/ coldness at night indicates onset of dry season/ no rain	H	22	13	40	25
9	Thunderstorm in April- May is associated with hailstones and heavy rainfall	I	48	16	0	36
10	Red sky indicates no rainfall	J	17	39	14	30
11	Unusual increased temperature during day and night especially in March indicates onset of rain	K	21	26	16	37
12	Rainbow in the west during S-W monsoon indicates upcoming rain	L	36	20	10	34
13	Red clouds indicate no rainfall	M	19	27	14	40
14	Warm breeze along in February- March indicates upcoming rain	N	42	12	05	41
15	Clouds with vertical development are associated with thunderstorm, lighting and heavy rainfall	O	33	11	07	49
16	Halo around the moon, indicates good rainfall	P	17	27	06	50

SRF – Short Range Forecast, **MRF** – Medium Range Forecast **LRF**- Long Range Forecast

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Table.8. Purpose of use of indigenous abiotic indicators for weather prediction with limited adoption among farmers N= 100

Sl. No.	Indicator	Indicator Code	SRF	MRF	LRF	Non-users
			%	%	%	%
1.	Rainbow in the east direction, indicates absence of rain/ less rainfall	Q	25	13	07	55
2.	Widespread cloud cover is associated with lighter showers on and off over several hours	R	18	02	0	80
3.	Whirlwinds or dust devils are clear indication of onset of dry seasons	S	03	09	06	82
4.	Occurrence of rain in presence of sunshine indicates absence of rain in near future	T	01	03	07	89

SRF – Short Range Forecast, MRF – Medium Range Forecast, LRF- Long Range Forecast

Percentage distribution of farmers based on purpose of use of each of the documented indigenous abiotic indicators is depicted as Figure 7. The results from the figure proved that, eleven of the indicators were used for SRF by majority of farmers and 06 indicators were used in MRF and three for LRF.

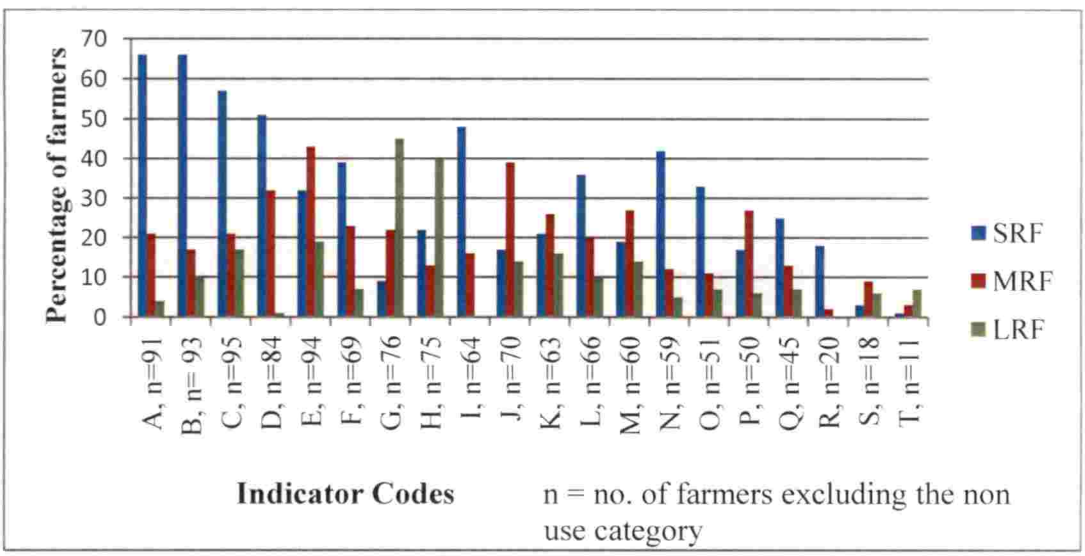

Figure 7. Distribution of farmers based on purpose of use of abiotic indicators

4. 3. 1. 2. Extent of use of indigenous abiotic factors by farmers

Extent of use of indigenous abiotic factors by farmers was measured in terms of regularity and time of use. Regularity with which the documented indigenous abiotic indicators were used by the farmers was measured as percentage of farmers rating in terms of its regular use, occasional use and heard but seldom used. Time of use was measured in terms of use of the indicator by farmers throughout the year, seasonally and sporadically used.

4. 3. 1. 2. 1. Regularity of indigenous abiotic factors by farmers

Based on the results, the indicators were categorized as those regularly used by farmers, occasionally used and heard but seldom used. The results indicated that majority of abiotic indicators (12 no.) were only seldom practiced by the farmers. However, the eight easier and common indicators were adopted by majority of farmers especially in the prediction of rains.

The list of abiotic indicators that were in regular and occasional use by majority of farmers is presented in Table 9. The results of the table showed that, majority of farmers were using only six indicators (A, B, C, D, E, I) on a regular basis and two indicators (G, H) were rated as being used occasionally. Indication of rain from thunder and lightning was the most regularly used abiotic indicator as rated by 65 per cent of farmers. This was followed by cool breeze along with moisture at 61 per cent and clear blue sky at 59 per cent farmer ratings. A significant inference from the results was that, the most regularly used indicators were related to prediction of rains which reiterate the importance of rains in farming. Kamsiime *et al.* (2013) indicated that, the amount of rainfall drives the agriculture potential and farming systems.

It can also be inferred from Table 9 that, reduction in water level in swamps, lagoons and *Kenies* indicating drought and drop in temperature at night forecasting onset of dry season were occasionally used as rated by 46 and 47 per cent of farmers respectively.

Table 9. List of indigenous abiotic indicators for weather prediction in regular & occasional use by farmers N= 100

Sl. No.	Indicator	Indicator Code	Regular use	Occasional use	Heard but seldom used
			%	%	%
1	Dark rolling clouds along with cool breeze indicate rainfall	A	42	27	31
2	Thunder and lightning indicate rainfall	B	65	16	19
3	Clear blue sky indicates no rainfall	C	59	21	20
4	Cool breeze along with moisture indicates rainfall	D	61	18	21
5	Clear moon and clear stars indicate no rainfall	E	48	16	36
6	Reduction in water level in swamps, lagoons and *Kenies* indicates drought	G	45	46	09
7	Drop in temperature at night / coldness at night indicates onset of dry season/ no rain	H	40	47	13
8	Thunderstorm in April- May is associated with hailstones and heavy rainfall	I	48	10	42

The list of indigenous abiotic indicators that were known to the farmers but were of seldom use is presented in Table 10. It is clear from Table 10 that, out of the twenty documented indicators, 12 numbers belonged to this group. The reason for seldom use of these can be attributed to the rareness of many of the listed natural features compared to the regularly used indicators. Another factor for not depending on these indicators can be its erratic nature arising from climate variations.

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Table 10. List of indigenous abiotic indicators for weather prediction in seldom use by farmers

N= 100

Sl. No.	Indicator	Indicator Code	Regular use	Occasional use	Heard but seldom used
			%	%	%
1	Dense fog in early morning indicates no rainfall	F	14	35	51
2	Red sky indicates no rainfall	J	10	15	75
3	Unusual increased temperature during day and night indicates rainfall	K	26	21	53
4	Rainbow in the western sky indicates rainfall	L	12	35	53
5	Red clouds indicate no rainfall	M	07	15	78
6	Warm breeze along in February- March indicates rainfall	N	09	14	77
7	Clouds with vertical development is associated with thunderstorm, lightning and heavy rainfall	O	06	28	66
8	Halo around the moon, indicates good rainfall	P	09	31	60
9	Rainbow in the east direction, indicates absence of rain/ less rainfall	Q	05	10	85
10	Widespread cloud cover is associated with lighter showers on and off over several hours	R	03	14	83
11	Whirlwinds or dust devils are clear indication of onset of dry seasons	S	03	05	92
12	Occurrence of rain in presence of sunshine indicates absence of rain in near future	T	01	07	92

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Indicator codes of Q, R, S and T were not at all popular in use as suggested by the very high percentage of non-users. The seldom use percentage for these indicators were 85 , 83, 92 and 92 respectively. The results were in line with the findings of Nganzi (2014).

Percentage distribution of farmers based on regularity of use of each documented indigenous abiotic indicator is depicted in Figure 8. The result proved that, six indicators were used regularly by majority of the farmers and two indicators were used occasionally. Majority of the farmers heard and seldom used twelve out of twenty indicators. The main reason for seldom use is the rare occurrence of many of the abiotic indicators compared to the regularly used indicators. This was in line with the findings of Bordoloi and Muzaddadi (2015).

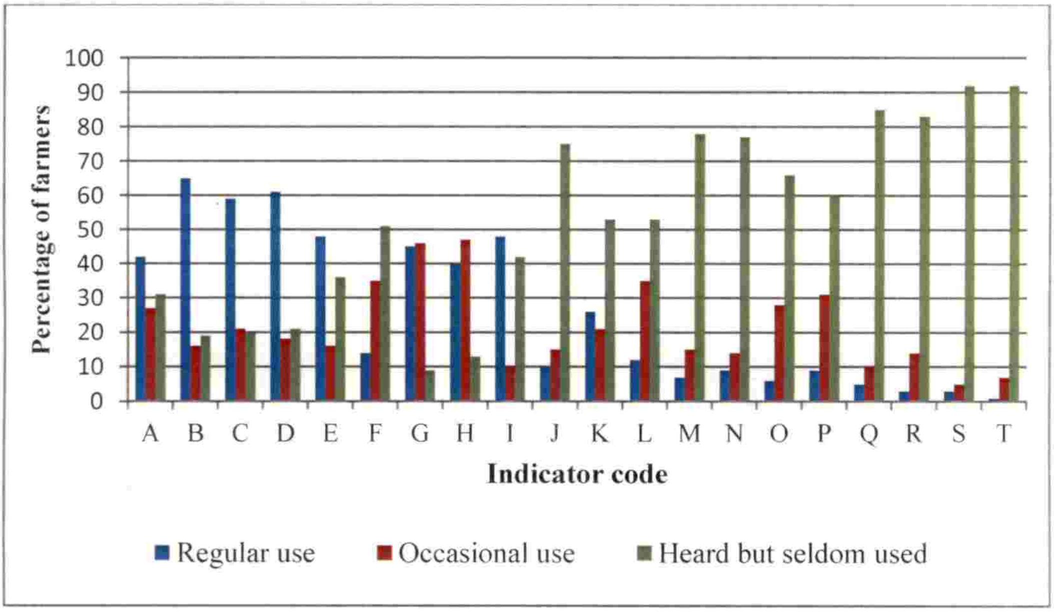

Figure. 8. Percentage distribution of farmers based on regularity of use of abiotic indicators

4. 3. 1. 2. 2 Time of use indigenous abiotic factors by farmers

Time of use related to the specific period during which a particular indicator was used by the farmers. Its measurement was based on use throughout the year, seasonal and sporadic use.

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Table 11. Indigenous abiotic indicators used maximum in a year for weather prediction by majority of farmers N=100

Sl. No.	Indicator code	Indicator Code	Throughout the year %	Seasonal use %	Sporadic use %
1	Dark rolling clouds along with cool breeze indicate rainfall	A	25	42	33
2	Thunder and lightning indicate rainfall	B	42	38	20
3	Clear blue sky indicates no rainfall	C	55	28	17
4	Cool breeze along with moisture indicates rainfall	D	17	61	22
5	Clear moon and clear stars indicate no rainfall	E	48	20	32
6	Dense fog in early morning indicates no rainfall	F	39	15	46
7	Reduction in water level in swamps, lagoons and *Kenies* indicates drought	G	13	43	44
8	Drop in temperature at night / coldness at night indicates onset of dry season/ no rain	H	13	42	45
9	Thunderstorm in April- May is associated with hailstones and heavy rainfall	I	10	42	48
10	Red sky indicates no rainfall	J	10	40	50

The results indicated that majority of farmers depend only on three indicators (B, C, E) throughout the year and two indicators (A, D) for seasonal weather prediction, these are presented in Table 11. Indigenous abiotic indicators used throughout the year were thunder and lightning (B, 42%), clear blue sky (C,

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55%) and clear moon and stars (E, 48%). Dark rolling clouds along with cool breeze (42%) and cool breeze along with moisture (61%) were used seasonally for predicting rainfall. It can also be inferred from the Table 11 that, the indicators F, G, H, I and J were frequently used and practiced sporadically.

The list of indigenous abiotic indicators that were used minimum in a year for weather prediction is presented in Table 12. It can be inferred from the results that, the indicator codes T, S and R are the minimum practiced indicators in a year. The percentages of farmers who practiced these indicators were only 9, 16 and 17 respectively.

Percentage distribution of farmers based on time of use of each of the documented abiotic indicators is given in the Figure 9. The results from the figure proved that, majority of the farmers used fifteen out of twenty indicators sporadically in a year and three indicators throughout the year and two indicators seasonally.

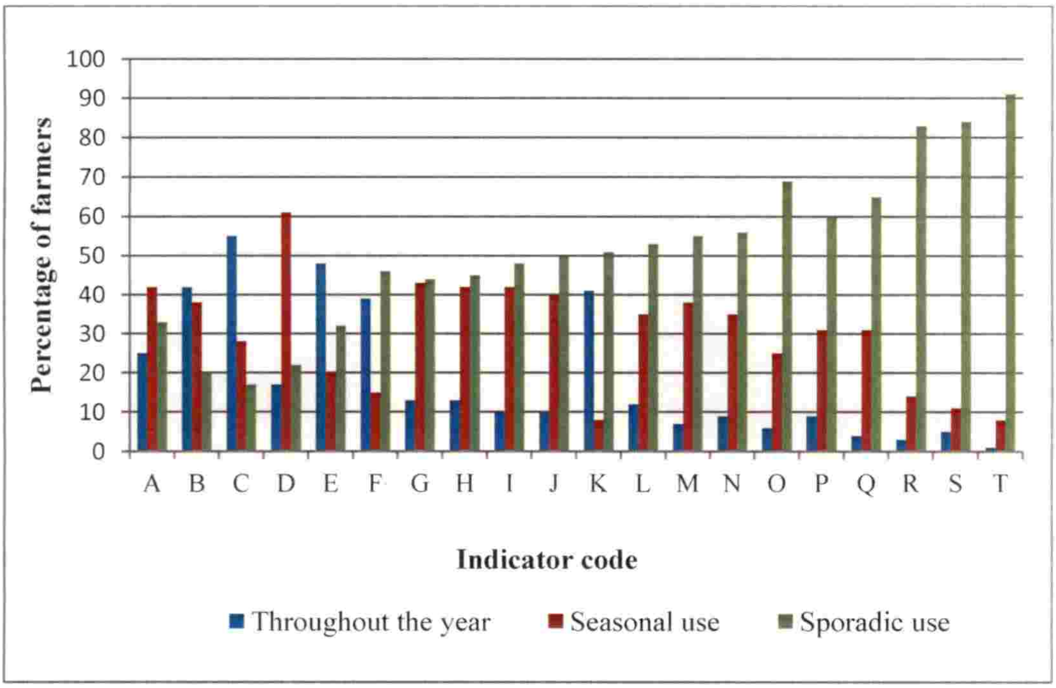

Figure. 9. Percentage distribution of farmers based on time of use of abiotic indicators

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Table 12. Indigenous abiotic indicators used minimum in a year for weather prediction by majority of farmers N=100

Sl. No.	Indicator	Indicator Code	Throughout the year	Seasonal use	Sporadic use
			%	%	%
1	Unusual increased temperature during day and night indicates rainfall	K	41	08	51
2	Rainbow in the western sky indicates rainfall	L	12	35	53
3	Red clouds indicate no rainfall	M	7	38	55
4	Warm breeze along in February- March indicates rainfall	N	9	35	56
5	Clouds with vertical development are associated with thunderstorm, lightning and heavy rainfall	O	6	25	69
6	Halo around the moon, indicates good rainfall	P	9	31	60
7	Rainbow in the east direction, indicates absence of rain/ less rainfall	Q	4	31	65
8	Widespread cloud cover is associated with lighter showers on and off over several hours	R	3	14	83
9	Whirlwinds or dust devils are clear indications of onset of dry seasons	S	5	11	84
10	Occurrence of rain in presence of sunshine indicates absence of rain in near future	T	1	8	91

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4. 3. 1. 3. Reliability of abiotic indicators based on farmers' perception

Reliability is the trustworthiness of an indicator in giving the desired outcome in the local situation as perceived by the farmer. Reliability of indicators expressed as farmers' perception in terms of always reliable, sometimes reliable and seldom reliable is presented in Table 13 and Figure 10. The results indicated that, out of the twenty listed indicators seven indicators were perceived to be reliable, eleven (D, F, J, K, L, M, N, O, P, R, S) were sometimes reliable and two (Q, T) were seldom reliable by majority of the farmers.

Indigenous abiotic indicators rated under reliable category were represented by codes A, B, C, E, G, H and I in Table 13. These codes corresponded to dark rolling clouds with cool breeze (45%), thunder and lightning (52%), clear blue sky (47%), clear moon and stars (44%), reduction in water level in swarms and lagoons (49%), drop in temperature at night (45%) and thunderstorm in April- May (45%). The result was in line with the findings of Rangalashmi (2008) and Nganzi (2014).

The results in Table 13 showed that the indicators D, F, J, K, L, M, N, O, P, R and S were denoted sometimes reliable by majority of the farmers. These codes represented cool breeze with moisture (45%), dense fog in early morning (42%), red sky (48%), increased temperature during day and night (53%), rainbow in the west (54%), red clouds (46%), warm breeze in February- March (48%), clouds with vertical development (48%), halo around the moon (53%), widespread cloud (55%) and whirl winds (48%). Of these indicators F, M and S corresponded to dry spell and D, J, K, L, N, O, P and R were related to the prediction of rainfall. However, in recent years, farmers have perceived that, the disparity in rainfall is becoming increasingly erratic and hard to predict, resulting in sometimes the reliability of these indicators. The results were in accordance with the findings of Rangalakshmi (2008).

The indictors Q and T were rated as seldom reliable by majority of the farmers. These codes corresponded to rainbow in the eastern sky (41%) and occurrence of rain in the presence of sunshine (57%) indicating no rainfall.

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Table 13. Perceived reliability of abiotic indicators for weather prediction based on farmer perception N=100

Sl. No	Indicator	Indicator code	Reliable	Sometimes reliable	Seldom reliable
			%	%	%
1	Dark rolling clouds along with cool breeze indicate rainfall	A	45	38	17
2	Thunder and lightning indicate rainfall	B	52	32	16
3	Clear blue sky indicates no rainfall	C	47	32	21
4	Cool breeze along with moisture indicates rainfall	D	20	45	35
5	Clear moon and clear stars indicate no rainfall	E	44	30	26
6	Dense fog in early morning indicates no rainfall	F	23	42	35
7	Reduction in water level in swamps, lagoons and *Kenies* indicates drought	G	49	36	15
8	Drop in temperature at night / coldness at night indicates onset of dry season/ no rain	H	45	38	17
9	Thunderstorm in April- May is associated with hailstones and heavy rainfall	I	45	36	19
10	Red sky indicates no rainfall	J	12	48	40
11	Unusual increased temperature during day and night indicates rainfall	K	21	53	26
12	Rainbow in the western sky indicates rainfall	L	10	54	36
13	Red clouds indicate no rainfall	M	16	46	38
14	Warm breeze in February- March indicates rainfall	N	12	48	40
15	Clouds with vertical development are associated with thunderstorm, lightning and heavy rainfall	O	24	48	28
16	Halo around the moon, indicates good rainfall	P	27	53	20
17	Rainbow in the east direction, indicates absence of rain/ less rainfall	Q	28	31	41
18	Widespread cloud cover is associated with lighter showers on and off over several hours	R	18	55	27
19	Whirlwinds or dust devils are clear indication of onset of dry seasons	S	17	48	35
20	Occurrence of rain in presence of sunshine indicates absence of rain in near future	T	18	25	57

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Percentage distribution of farmers based on reliability of each of the documented abiotic indicators is given in the Figure 10. The results from the figure proved that seven indicators were reliable, eleven indicators were rated as sometimes reliable and two were seldom reliable.

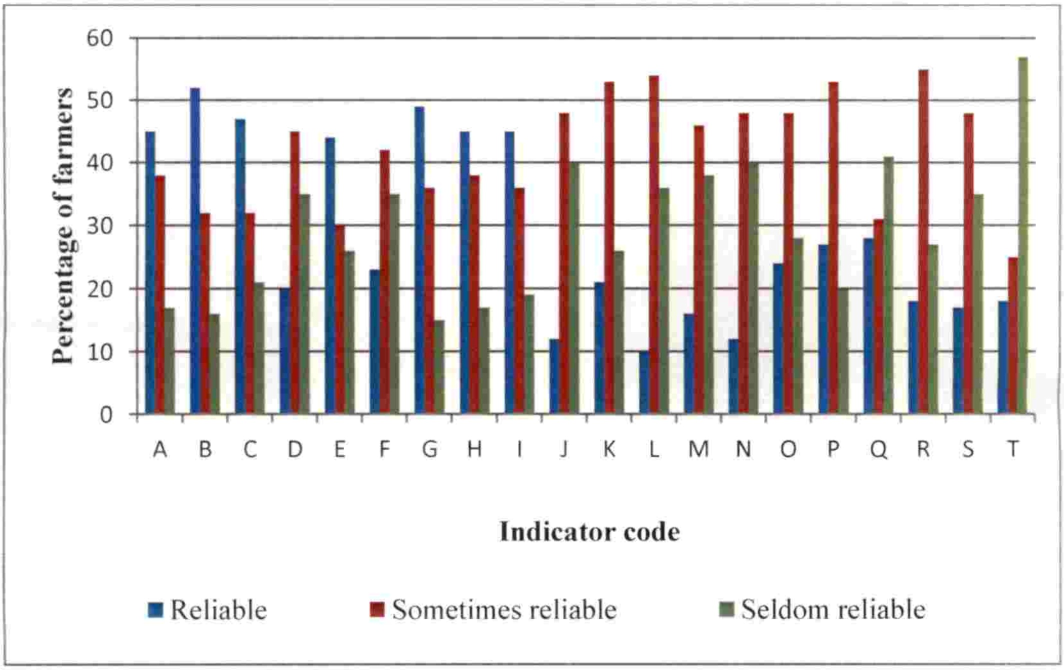

Figure.10. Percentage distribution of farmers based on reliability of abiotic indicators

4. 3. 1. 4 Use Validity Score of documented abiotic indicators based on farmers' perception

Documented ITKs were validated through farmer participatory process using Use Validity Score (UVS). The UVS of a particular ITK has three dimensions viz. purpose of use, extent of use and perceived reliability. The calculation of UVS was done as explained in the methodology. On the basis of mean (2.18) and standard deviation (0.62) of UVS, the indicators were classified into three groups as indicators with High UVS, Medium UVS and Low UVS. Ranking of ITKs was also done using UVS.

Indigenous abiotic indicators with high UVS (>2.80) based on farmers' perception are given in Table 14. Out of the twenty abiotic indicators, four

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indicators that had high use validity among farmers. The clear blue sky, clear stars and moon at night were features, that indicated no rainfall and dark rolling clouds along with cool breeze, thunder and lightning indicated heavy rainfall. These indicators had high scope in local crop weather forecast.

Table 14. Indigenous abiotic indicators with high use validity (>2.80) based on farmers' perception

Sl. No.	Indicator	Raw UVS	Weighted UVS
1	Clear blue sky indicates no rainfall	9.14	3.33
2	Thunder and lightning indicate rainfall	9.12	3.15
3	Dark rolling clouds along with cool breeze indicate rainfall	8.72	2.94
4	Clear moon and stars indicate no rainfall	8.52	2.83

Indigenous abiotic indicators with medium UVS based on farmers' perception are given in Table 15. Thirteen indicators had medium UVS scores ranging between 2.8 and 1.56 among farmers. These included unusual increasing temperature during day and night, rainbow in the western sky, warm breeze in February- March, cool breeze along with moisture and halo around the moon that forecasted upcoming rains. Clouds with vertical development were associated with thunderstorm, lightning and thunderstorm in April- May were associated with hailstones and heavy rainfall which also had medium UVS among farmers. Dense fog in early morning, drop in temperature at night, reduction in water level in swamps and lagoons and *Kenies,* red sky and red clouds in the evening and rainbow in the eastern sky indicated absence of rain or onset of dry season. These were also rated to have only medium level of UVS among farmers.

Table 15. Indigenous abiotic indicators with medium use validity (between 1.56 – 2.80) based on farmers' perception

Sl. No.	Indicator	Raw UVS	Weighted UVS
1	Cool breeze along with moisture	8.15	2.75
2	Reduction in water level in swamps, lagoons and *Kenies* indicates drought	7.72	2.60
3	Thunderstorm in April- May is associated with hailstones and heavy rainfall	7.12	2.39
4	Drop in temperature at night / coldness at night indicates onset of dry season/ no rain	7.04	2.38
5	Dense fog in early morning indicates no rainfall	6.77	2.27
6	Unusual increased temperature during day and night	6.72	2.24
7	Rainbow in the western sky indicates rainfall	6.19	2.07
8	Red sky indicates no rainfall	5.98	2.03
9	Red clouds indicate no rainfall	5.63	1.87
10	Halo around the moon, indicates good rainfall	5.43	1.86
11	Warm breeze in February- March indicates rainfall	5.40	1.81
12	Clouds with vertical development are associated with thunderstorm, lightning and heavy rainfall	5.13	1.73
13	Rainbow in the east direction, indicates absence of rain/ less rainfall	4.75	1.61

Indigenous abiotic indicators with low Use Validity Score (< 1.56) based on farmers' perception are given Table 16. Three indicators that had low UVS scores among farmers were, occurrence of rain in presence of sunshine, whirlwinds or dust devils that indicated onset of dry season. Also, widespread cloud cover indicated light showers intermittently over several hours.

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Table 16. Indigenous abiotic indicators with low use validity (<1.56) based on farmers' perception

Sl. No.	Indicator	Raw UVS	Weighted UVS
1	Widespread cloud cover is associated with lighter showers on and off over several hours	4.02	1.35
2	Whirlwinds or dust devils are clear indication of onset of dry seasons	3.82	1.28
3	Occurrence of rain in presence of sunshine indicates absence of rain in near future	3.46	1.17

Most of the indicators had medium (12 no.) or high use validity (5 no.) among farmers. The results showed that despite the advancements in weather prediction methods and availability of scientific forecasts, farmers continue to rely on indigenous knowledge. This can be attributed to the low perceived reliability of formal sources of weather information among farmers and also to their limited accessibility in required time. Generally, the official weather forecasts are not location specific or area specific which make the farmer relay on the local indicators for predicting weather. Therefore, there exists a need for weather forecasts which are more location specific from Department of Agriculture and IMD for efficient crop management practices and to reduce crop loss. And integration of indigenous knowledge with scientific forecast will improve the reliability of weather forecasting. Shankar *et al.* (2008) opined that, the integration of scientific and traditional weather forecast systems would improve the uncertainties related to weather prediction.

Another significant inference from the results was that, the highly using indicators among farmers were mostly based on generalized observations of abiotic factors. As the difficulty of observation increased in terms of requirement of specific details, the popularity of indicator showed a decreasing trend towards medium to low levels. Therefore, integrating this information into training programmes for farmers will better equip them to use these to their advantage.

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4. 3. 2 Validation of abiotic indicators based on published research findings

The documented abiotic indicators were also validated on thematic content analysis based on existing theory and findings from scientific reports of research. Accordingly, the reported abiotic indicators for weather prediction were categorized into two groups viz. 1) Scientifically validated abiotic indicators, 2) Farmers' experientially validated abiotic indicators. The evaluation details are presented below.

4. 3. 2. 1 Scientifically validated abiotic indicators for weather prediction

The validation using available theoretical explanations and findings from various published research sources identified nine abiotic indicators with scientific proof. Most of the evaluated abiotic indicators had only theoretical explanation and are presented in Table 17. The indicators and the theoretical explanations are given below.

a) Dark rolling clouds along with cool breeze indicate rainfall

Aherns (2011) explained that rain clouds are generally black or grey in colour instead of white because of their thickness and the nature of the particles present in the cloud. Cloud gets thicker and denser as it gathers more water droplets and ice crystals. When thickness of cloud increases light reflection and scattering also increase resulting in less light penetration into the clouds so that it appears as grey/ black. Cool breeze with moisture triggers saturation with already existing clouds resulting in upcoming rain.

b) Widespread cloud cover is associated with on and off light shower

Aherns (2011) elucidate that, these are stratus, stratocumulus and nimbostratus cloud, which develop horizontally and are uniform and flat, producing a gray layer of cloud cover which may cause periods of light precipitation or drizzle. Nimbostratus clouds are generally wet looking clouds associated with more or less continuously falling rain. The intensity of this precipitation is usually light or moderate.

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c) Clouds with vertical development associated with thunderstorm and lightning

Clouds with vertical development are cumulonimbus clouds. These clouds develop on an unstable atmosphere, atmospheric instability, moisture and lift present and then strong updrafts can develop in the cumulus cloud leading to a mature deep cumulonimbus cloud resulting in a thunderstorm producing heavy rain. In addition, cloud electrification occurs within cumulonimbus clouds due to many collisions between charged water droplet, graupel (ice-water mix), and ice crystal particles, resulting in lightning and thunder explained by Vishnu *et al.* (2013).

d) Halo around the moon indicates rainfall

Aherns (2011) explained that, halo around the moon usually indicates an advancing warm front, which means precipitation. The halo is caused by the refraction of light as it passes through ice crystals and ice crystal–type clouds (cirrostratus) which are often the forerunners of an approaching rainstorm.

e) Clear blue sky/ moon/ stars were associated with no rainfall

Aherns (2011) explained that, there is strong relationship between weather variables and nature of the atmosphere. In a high-pressure system, air tends to sink near high pressure centers which inhibit the precipitation and cloud formation, resulting in clear atmospheric conditions.

f) Red clouds and sky were associated with no rainfall

Aherns (2011) explained that, sinking of air will occur in a high-pressure system. When the sinking air comprises of high concentration of dust and larger particles, these larger particles scatter the longest wavelengths (red light) more efficiently and sky and appears as red. High pressure systems are generally associated with fair weather. Out of the twenty listed indicators eight indicators were explained with the help of published research findings.

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Table 17. Scientifically validated abiotic indicators for weather prediction

Sl. No.	Indicator	Reported state/ country	Similar indicator reported by	Reference
I. Indicators related prediction of rainfall				
1	Dark rolling clouds along with cool breeze	Kerala Madhya Pradesh Malawi	KAU, 2015 Singh, 2006 Joshua *et al.*, 2011	Ahrens, 2011
2	Widespread cloud covers (low clouds)	Andhra Pradesh Malawai	Shankar *et al.*, 2008 Joshua *et al.*, 2011	Ahrens, 2011
3	Clouds with vertical development	Uganda	Nganzi, 2014	Vishnu *et al.*, 2013
4	Halo around the moon	Kerala Tamil Nadu Zimbabwe	KAU, 2015 Anandaraja*et al.*, 2008 Risiro, *et al.*,2012	Ahrens, 2011
II	**Indicators related to prediction of no rainfall/ dry season**			
5	Clear blue sky	Kerala	KAU, 2015	Ahrens, 2011
6	Clear moon and stars	Madhya Pradesh	Singh, 2006	Ahrens, 2011
7	Red clouds	Uganda	Nganzi, 2014	Ahrens, 2011
8	Red sky	Kerala	KAU, 2015	Ahrens, 2011

4. 3. 2. 2 Farmers experientially validated abiotic indicators

The abiotic indicators which had no scientific proof or explanation but were popular among farmers enlisted in Table 18. Out of the twenty listed indicators majority (12 no.) of the indicators were come under this category. These indicators needed future research to check its rationality or irrationality.

Table 18. Abiotic indicators reported as rational by farmers but without scientific proof

Sl. No.	Indicator	Similar indicator reported by
1. Indicators related prediction of rainfall		
1	Cool breeze along with moisture	-
2	Warm breeze in February- March	-
3	Unusual increased temperature during day and night	Risiro, *et al.*, 2012
4	Rainbow in the western sky indicate rainfall	Shankar *et al.*, 2008
5	Thunder and lightning indicate rainfall	Shankar *et al.*, 2008
6	Thunderstorm in March – May associated with hailstorms	-
2. Indicators related prediction of no rainfall / onset of dry season/ drought		
7	Dust devils or whirlwinds	Risiro, *et al.*, 2012
8	Reduction in water levels in swamps, lagoons and *Kenies*	Nganzi, 2015
9	Occurrence of rain in presence of sunshine	Nganzi, 2015
10	Rainbow in the eastern sky	Anandaraja *et al.*, 2008
11	Dense fog in early morning	Anandaraja *et al.*, 2008
12	Drop in temperature at night/ coldness in the night	Nganzi, 2015

4. 3. 3 Validation of biotic indicators based on farmers' perception

Use Validity Score (UVS) was used in the validation of documented biotic indicators by farmers. Purpose of use, extent of use (measured in terms of regularity and time of use), and perceived reliability as reported by farmers were used as measures of use validity.

4. 3. 3. 1 Purpose of use of biotic indicators based on farmers' perception

Purpose of use explained whether the farmer used an indicator for short range forecast (SRF), medium range forecast (MRF) or long-range forecast (LRF). Purpose for which indigenous biotic indicators were used by above 50 per cent of the respondents is given in Table 19.

The results from Table 19 show that out of twenty-one indicators, twelve indicators were used for SRF and five indicators for MRF and four indicators for LRF by majority of the farmers. It is evident from the table that, the indicator codes H, I, J, K, L, V, X, Y, CC, EE, GG and HH denoted the SRF indicators. These codes represented earthworms coming out of the ground (42%), dragonfly flying low (78%), swarming of winged termites (88%), ants transporting eggs to safer place (41%), cicada making noise in groups (27%), frogs croaking near swampy areas (78%), owl making special sounds (27%), low flights of grey wagtails (68%), peacock making special sounds (76%), chickens staying under shade (41%), jumping of cattle (43%) and unusual barking of street dogs (43%) respectively. These indicators were reported to be used for SRF of rainfall. These results are in line with the findings of Acharya (2011).

The indicators used in MRF were represented by the codes D, U, DD, G and R of Table 19. These codes corresponded to softening of stored tamarind (56%), appearance of fish swimming near the surface of ponds (26%), hornbill making special noise (48%), flowering of jasmine (28%) and abundance of white color butterflies (34%) respectively.

The LRF indicators E, F and M were related to the prediction of no rainfall or drought, whereas indicator 'A' was related to the prediction of rains.

Table 19. Purpose of use of indigenous biotic indicators for weather prediction with high adoption among farmers N = 100

Sl. No.	Indicator	Indicator Code	SRF	MRF	LRF	Non-users
			%	%	%	%
1	Heavy flowering of South Indian Plum indicates good rainfall	A	05	14	36	45
2	Softening of stored tamarind indicates rainfall	D	11	56	05	28
3	Heavy flowering of mango tree indicates drought	E	04	11	48	37
4	Flowering of night blooming jasmine indicates no rainfall	F	17	19	28	36
5	Early flowering of Golden shower tree indicates increasing temperature	G	25	39	15	21
6	Earthworms come out of the ground in rainy season	H	42	11	08	39
7	Dragon fly flying low in groups indicates rainfall	I	78	03	01	18
8	Swarming of winged termites in the evening indicates rainfall	J	88	03	01	08
9	Ants transport eggs to safer place indicates rainfall	K	41	18	06	35
10	Cicada singing in groups indicates upcoming rain	L	27	15	12	46
11	Army worms seen in large numbers in paddy indicate no rainfall	R	10	37	12	41
12	Butterflies seen in large numbers indicate no rainfall	T	15	19	34	32
13	Fish swimming near the surface of pond indicates rainfall	U	18	26	11	45
14	Frogs croaking near swampy areas in groups indicate rainfall	V	78	13	04	05
15	Owl making special sounds indicates rainfall	X	27	21	06	46
16	Grey wagtail flying down to the earth in groups indicates rainfall	Y	68	09	03	20
17	Peacock making special sounds indicates rainfall	CC	76	15	04	05
18	Indian grey hornbill making noise indicates rainfall	DD	06	74	11	09
19	Chicken staying under shade and bathing in dust indicate rainfall	EE	41	14	06	39
20	Jumping of cattle indicates rainfall	GG	43	14	04	39
21	Unusual barking and restlessness of dogs indicate rainfall	HH	43	11	08	38

SRF – Short Range Forecast, MRF – Medium Range Forecast, LRF – Long Range Forecast

The indigenous biotic indicators for weather prediction which are used by less than 50 per cent of the farmers are presented in Table 20. The results from the table showed that four biotic indicators were used for MRF and five indicators each were used for SRF and LRF predictions.

Table 20. Purpose of use of indigenous biotic indicators for weather prediction with limited adoption among farmers N = 100

Sl. No.	Indicator	Indicator Code	SRF	MRF	LRF	Non-users
			%	%	%	%
1	Fully developed three seeds in the fruits of Flame of forest indicate rainfall	B	01	04	09	86
2	Softening of stored flowers of Illipe butter tree indicates rainfall	C	12	19	04	65
3	Biting nature of housefly indicates rainfall	M	15	8	01	76
4	Honey bee hiding their honey comb and reduced bee activity indicate rainfall	N	05	24	02	69
5	Spider making thicker vertical webs relative to earth indicates rainfall	O	03	07	01	89
6	Crabs making sloppy holes in soil indicate rainfall	P	09	06	02	83
7	Appearance of large number of grasshoppers indicates upcoming rain	Q	07	14	23	56
8	Termites developing new mounts indicate upcoming rain	S	04	24	04	68
9	Large number of snakes indicate good rainfall	W	12	14	16	58
10	Eagle making special sounds and flying low indicate rainfall	Z	13	11	04	72
11	Unusual chirping of Hill myna indicates rainfall	AA	07	05	02	86
12	Greater Coucal making special sounds indicates rainfall	BB	08	05	03	84
13	Crows crying during the night indicate drought	FF	01	12	18	69
14	Malabar giant squirrel seen in large numbers indicates no rainfall	II	07	05	11	77

SRF – Short Range Forecast, MRF – Medium Range Forecast, LRF – Long Range Forecast

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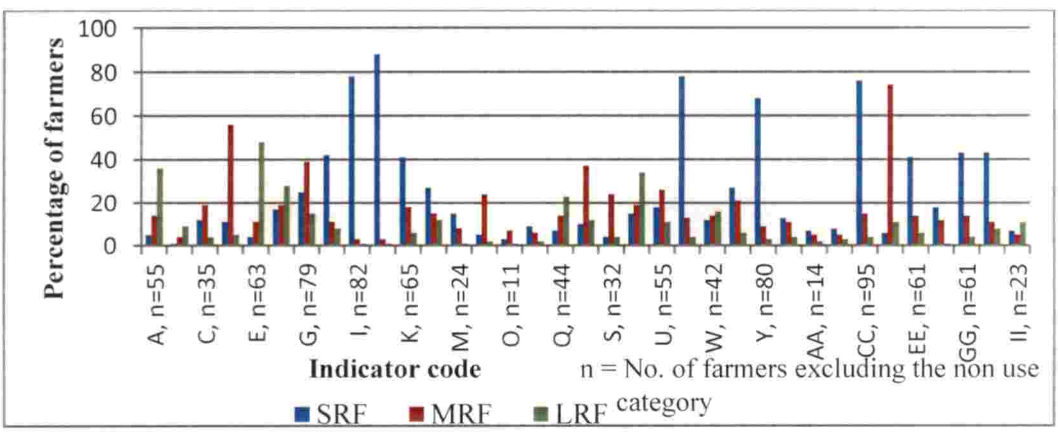
The result from Table 20 showed that indicator codes M, P, Z, AA and BB were used for SRF of rainfall. These codes represent biting nature of housefly (15%), sloppy hole making of crabs (9%), eagle making special sounds (13%), unusual chirping of hill myna (7%) and greater coucal making special sounds (8%) respectively.

Indicators used for MRF were represented by codes C, N, O and S of Table 20. These were corresponding to softening of stored flowers of illipe butter tree (19%), reduced bee activity (24%), web making fashion of spiders (7%) and new mount development of termites (24%) respectively.

It is evident from the Table 20 that, five indicators were used for LRF. These are represented by the codes B, Q, W, FF and II and these codes corresponded to seed development of flame of forest tree (9%), large number of grasshoppers in the field (23%), increased presence of snakes (16%), crow crying during night (18%), Malabar giant squirrel seen in large numbers (11%) respectively. Among the LRF indicators, FF and II were related to prediction of no rainfall and indicators B, Q and W were related to rainfall prediction.

Percentage distribution of farmers based on purpose of use of each of the documented biotic indicators is depicted in Figure 11. The result from the figure proved that, eighteen indicators were used for SRF by majority of the farmers and eight indicators were used in LRF and nine indicators for MRF. This substantiated the importance placed by farmers on SRF in crop planning and management which is corroborated from the findings of Angchok and Dubey (2006).

Figure. 11. Distribution of farmers based on purpose of use of biotic indicators



SRF – Short Range Forecast, MRF – Medium Range Forecast, LRF – Long Range Forecast

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4. 3. 3. 2 Extent of use of biotic indicators based on farmers' perception

Extent of use of biotic indicators by farmers was measured in terms of regularity and time of use. Regularity with which the documented indigenous biotic indicators were used by the farmers was measured as percentage of farmers rating in terms of its regular use, occasional use and heard but seldom used. Time of use was measured in terms of use of the indicator by farmers throughout the year, seasonally and sporadically used.

4. 3. 3. 2. 1 Regularity of use of indigenous biotic factors by farmers

Based on the results, the indicators were categorized as those regularly used by farmers, occasionally used and heard but seldom used. The results indicated that, majority of biotic indicators (28 no.) were only seldom practiced by farmers. However, the seven easier and common indicators were adopted by majority of farmers especially in the prediction of rain.

A list of indicators that were in regular and occasional use by majority of the farmers are presented in Table 21. The result from the table showed that, majority of the farmers were using five indicators (J, V, Y, GG, EE) on a regular basis and two indicators (D, I) were rated as being used occasionally. The indication of rain from swarming of winged termites in the evening was rated to be of regular use by 64 per cent of the farmers. This was followed by jumping of cattle at 50% and chickens staying under shade and bathing in dust at 48% ratings. A significant inference from the results was that, the regularly used indicators are interlinked with their daily livelihood and are quite common throughout the year. The result was in line with the findings of Nganzi (2014).

It can be also be inferred from the Table 21 that, softening of stored tamarind and dragon fly flying low in groups forecasting rainfall were occasionally used as rated by 48 and 43 per cent of farmers respectively.

The list of indigenous biotic indicators that were known to the farmers but were of seldom use are presented in Table 22. It can also be inferred from the results in the table that, 22 out of the thirty-five documented indicators belonged to this group. The reason for seldom use of these can be attributed to the rareness of many of the listed indicators during a year and the specific skill required to identify it in the natural environments.

The indicators O, B, C and P were not at all popular in use as suggested by very high percentage of nonusers. The seldom use percentage for these indicators were 97, 96, 91 and 91 per cent respectively. These codes corresponded to spider making thicker vertical webs relative to earth, seeds in the fruits of flame of forest, softening of stored flowers of illipe butter tree and crabs making sloppy holes in soil. All these codes corresponded to rainfall. It can be inferred from the findings that, these indicators needed close observations and they were not of regular common occurrence. This can be the probable reason for the majority of farmers for not practicing it regularly.

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Table 21. List of indigenous biotic indicators for weather prediction of regular and occasional use by farmer N = 100

Sl. No	Indicator	Indicator code	Regular use	Occasional use	Heard but seldom used
			%	%	%
1	Softening of stored tamarind indicates rainfall	D	20	48	32
2	Heavy flowering of mango tree indicates drought	E	14	38	48
3	Early flowering of golden shower tree indicates increasing temperature	G	37	24	39
4	Dragon fly flying low in groups indicates rainfall	I	23	43	34
5	Swarming of winged termites in the evening indicates rainfall	J	64	26	10
6	Ants transporting eggs to safer place indicate rainfall	K	19	36	45
7	Butterflies seen in large numbers indicate no rainfall	T	17	36	47
8	Frogs croaking near swampy areas in groups indicate rainfall	V	44	32	24
9	Grey wagtail flying down to the earth in groups indicates rainfall	Y	43	28	29
10	Peacock making special sounds indicates rainfall	CC	14	38	48
11	Indian grey hornbill making noise indicates rainfall	DD	28	29	43
12	Jumping of cattle indicates rainfall	GG	50	22	28
13	Chicken staying under shade and bathing in dust indicate rainfall	EE	48	19	33

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Table 22. List of indigenous biotic indicators for weather prediction seldom used by majority farmers N = 100

Sl. No	Indicator	Indicator code	Regular use	Occasional use	Heard but seldom used
			%	%	%
1	Heavy flowering of South Indian Plum indicates rainfall	A	14	26	60
2	Fully developed three seeds in the fruits of flame of forest indicate rainfall	B	0	4	96
3	Softening of stored flowers of illipe butter tree indicates rainfall	C	2	7	91
4	Flowering of night blooming jasmine indicates onset of dry season	F	17	27	56
5	Earthworms coming out of the ground indicate good rainfall	H	12	26	62
6	Cicada singing in groups indicates upcoming rain	L	11	27	62
7	Biting nature of housefly indicates rainfall	M	5	11	84
8	Honey bee hiding their honey comb and reduced bee activity indicate rainfall	N	8	8	84
9	Spider making thicker vertical webs relative to earth indicates rainfall	O	1	2	97
10	Crabs making sloppy holes in soil indicate rainfall	P	4	5	91
11	Appearance of large number of grasshoppers indicates upcoming rain	Q	11	19	70
12	Army worms seen in large numbers in paddy indicate no rainfall	R	16	27	57
13	Termite developing new hills indicates rainfall	S	6	12	82
14	Emergence of fish swimming near the pond indicates good rainfall	U	14	24	62
15	Snakes seen in large numbers indicate good rainfall	W	13	15	72
16	Owl making special sounds indicates good rainfall	X	15	18	67
17	Eagle flying down to earth and making special noise indicate rainfall	Z	12	13	75
18	Unusual chirping of hill myna indicates rainfall	AA	4	7	89
19	Greater Coucal making special sounds indicates rainfall	BB	5	8	87
20	Crows crying during the night indicate drought	FF	7	10	83
21	Unusual barking and restlessness of street dogs indicate rainfall	HH	14	27	59
22	Malabar giant squirrel seen in large numbers indicates no rainfall	II	8	9	83

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Percentage distribution of farmers based on regularity of use of each documented indigenous biotic indicator is depicted as Figure 12. The results from the figure proved that, five indicators were used regularly by majority of the farmers and two indicators were used occasionally. Majority of the farmers had heard but seldom used twenty-eight out of the thirty-five indicators documented. The main reason for this can be attributed to the rare occurrence of many of the biotic indicators compared to the regularly used indicators. This was in line with the findings of Bordoloi and Muzaddadi (2015).

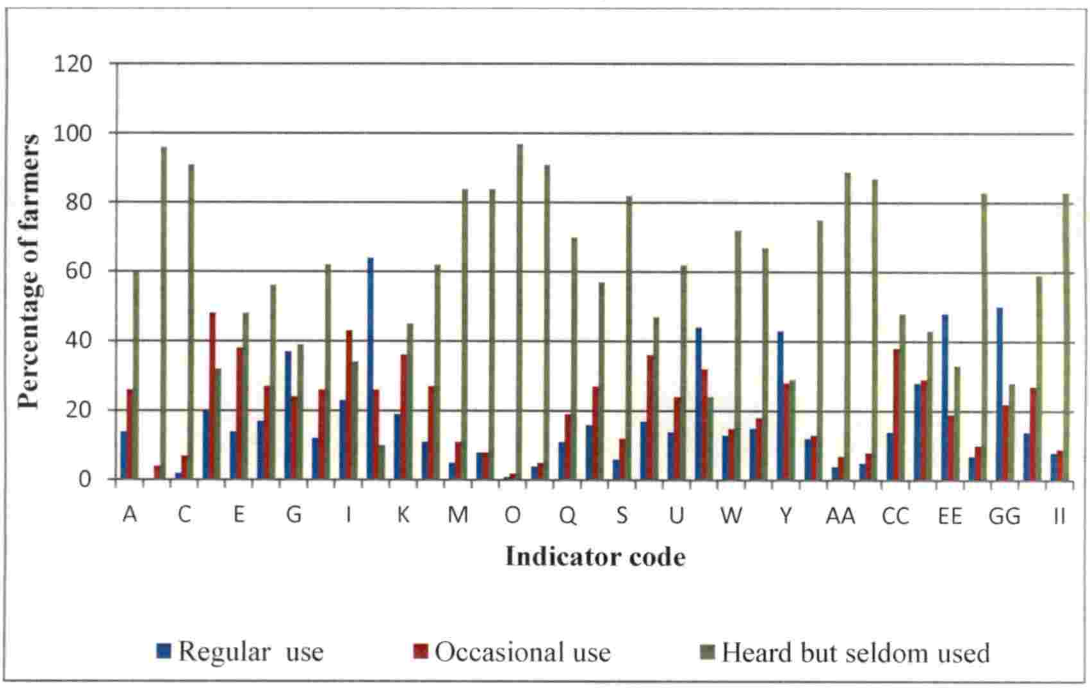

Figure. 12. Percentage distribution of farmers based on regularity of use of biotic indicators

4. 3. 3. 2. 2 Time of use of indigenous biotic factors by farmers

Time of use related to the specific period during which an indicator was used by the farmers. Its measurement was based on three dimensions viz. throughout the year use, seasonal use and sporadic use as reported by farmers.

The results indicated that majority of farmers depended only on nine indicators (G, I, K, M, T, V, Y, GG, EE) for weather prediction throughout the year and three indicators (D, J, HH) were only of seasonal use. The details of these are presented in Table 23. Indigenous biotic indicators used throughout the year were flowering of golden shower tree (G, 48%), dragon fly flying low in groups (I, 71%), ants transporting eggs to safer places (K, 46%), biting nature of housefly (M, 45%), frogs croaking near swampy areas (V, 64%), grey wagtail flying down to the earth (Y, 54%), jumping of cattle (GG, 46%), and chickens staying under shade and bathing in dust (EE, 69%). Softening of stored tamarind (56%), swarming of winged termites in the evening (J, 72%) and restlessness of street dogs (HH, 46%) were used seasonally by farmers for predicting rainfall.

The list of indigenous biotic indicators that were used minimum in a year for weather prediction are presented in Table 24. It can be inferred from the results that, seeds in the fruits of flame of forest, spider making thicker vertical webs relative to earth, crabs making sloppy holes in soil were the seldom practiced indicators. They were all related to the prediction of rainfall and were practiced only by 11, 11 and 15 per cent of farmers respectively. All these required very close observations and continuous monitoring which could have affected its popularity among farmers.

Table 23. Indigenous biotic indicators used maximum in a year for weather prediction by majority of farmers N=100

Sl. No.	Indicator	Indicator code	Through out the year	Seasonal	Sporadic use
1	Softening of stored tamarind indicates rainfall	D	11	56	33
2	Early flowering of golden shower tree indicates increasing temperature	G	48	19	33
3	Dragon fly flying low in groups indicates rainfall	I	71	7	22
4	Swarming of winged termites in the evening indicates rainfall	J	19	72	9
5	Ants transporting eggs to safer place indicates rainfall	K	46	13	41
6	Biting nature of housefly indicates rainfall	M	45	23	32
7	Butterflies seen in large numbers indicate no rainfall	T	41	23	36
8	Frogs croaking near swampy areas in groups indicate rainfall	V	64	21	15
9	Grey wagtail flying down to the earth in groups indicates rainfall	Y	54	21	25
10	Jumping of cattle indicates rainfall	GG	46	19	35
11	Unusual barking and restlessness of street dogs indicate rainfall	HH	13	46	41
12	Chicken staying under shade and bathing in dust indicate rainfall	EE	69	13	18

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Table 24. The list of indigenous biotic indicators that were used minimum in a year for weather prediction N = 100

Sl. No.	Indicator	Indicator code	Throughout the year	Seasonal use	Sporadic use
1	Heavy flowering of South Indian Plum indicates rainfall	A	9	39	52
2	Fully developed three seeds in the fruits of flame of forest indicate rainfall	B	1	10	89
3	Softening of stored flowers of illipe butter tree indicates rainfall	C	11	20	69
4	Heavy flowering of mango tree indicates drought	E	4	45	51
5	Flowering of night blooming jasmine indicates onset of dry season	F	17	19	64
6	Earthworms coming out of the ground indicate good rainfall	H	1	46	53
7	Cicada singing in groups indicates upcoming rain	L	16	25	59
8	Honey bee hiding their honey comb and reduced bee activity indicate rainfall	N	12	16	72
9	Spider making thicker vertical webs relative to earth indicates rainfall	O	8	3	89
10	Crabs making sloppy holes in soil indicate rainfall	P	6	9	85
11	Appearance of large number of grasshoppers indicates upcoming rain	Q	28	11	61
12	Army worms seen in large numbers in paddy indicates no rainfall	R	34	13	53
13	Termite developing new hills indicates rainfall	S	23	5	72
14	Emergence of fish swimming near the pond indicates good rainfall	U	24	25	51
15	Snakes seen in large numbers indicate good rainfall	W	16	15	69
16	Owl making special sounds indicates good rainfall	X	21	26	53
17	Eagle flying down to earth and making special noise indicate rainfall	Z	4	11	85
18	Unusual chirping of hill myna indicates rainfall	AA	2	6	92
19	Greater Coucal making special sounds indicates rainfall	BB	2	5	93
20	Peacock making special sounds indicates rainfall	CC	14	23	63
21	Indian grey hornbill making noise indicates rainfall	DD	10	38	52
22	Crows crying during the night indicate drought	FF	12	4	84
23	Malabar giant squirrel seen in large numbers indicates no rainfall	II	9	10	81

Percentage distribution of farmers based on time of use of each of the documented biotic indicators is given in the Figure 13. The results from the figure proved that, majority of the farmers used twenty-three out of 35 indicators sporadically in a year and nine indicators throughout the year and three indicators seasonally.

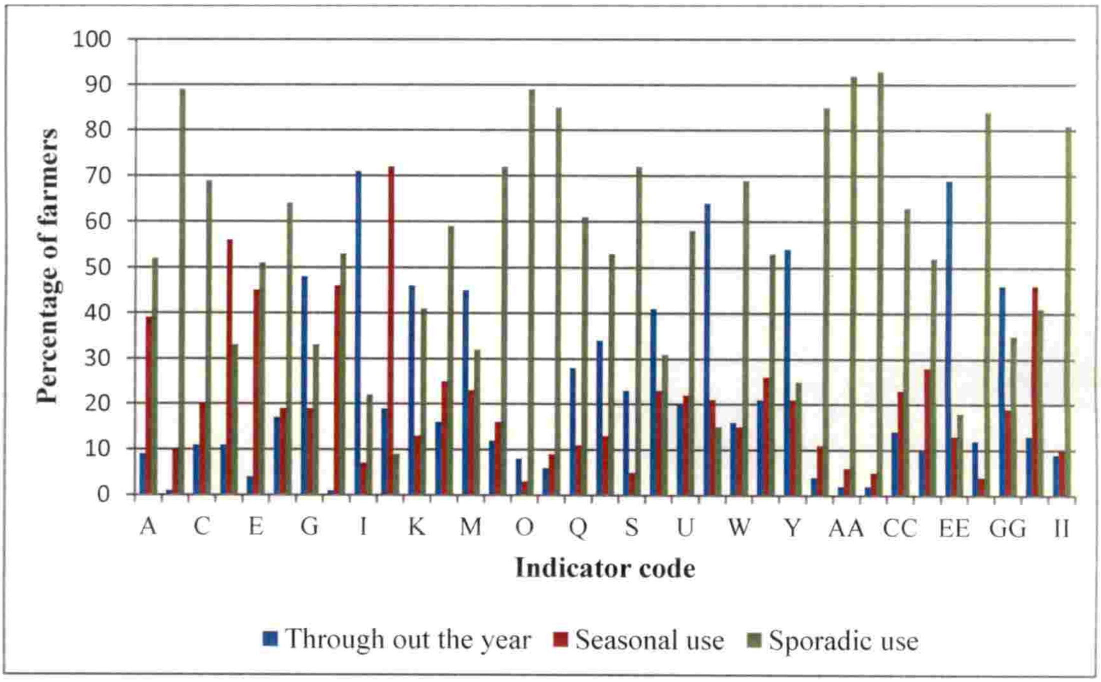

Figure. 13. Percentage distribution of farmers based on time of use of biotic indicators

4. 3. 3. 3. Reliability of biotic indicators based on farmers' perception

Reliability of biotic indicators gave the accuracy of results in repeated use as perceived by the farmers. The results expressed in a continuum ranging from always reliable, sometimes reliable and seldom reliable are presented in Table 25. Indigenous biotic indicators rated under reliable category were represented by codes D, G, J, K, Y and CC. These codes corresponded to softening of stored tamarind (43%), flowering of golden shower tree (43%), swarming of winged termites (73%), ants transporting eggs to safer places (46%), grey wagtail flying down to the earth (49%) and peacock making special sounds (67%). The codes I, V and DD were rated as sometimes reliable and represented dragon fly flying low (46%), frogs croaking near swampy areas (45%) and grey hornbill making noise (43%). All of these indicated upcoming rainfall.

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Table 25. List of indigenous biotic indicators for weather prediction with high reliability among farmers N = 100

Sl. No.	Indicator	Indicator code	Reliable	Sometimes reliable	Seldom reliable
1	Softening of stored tamarind indicates rainfall	D	43	24	33
2	Heavy flowering of mango tree indicates drought	E	13	39	48
3	Flowering of night blooming jasmine indicates onset of dry season	F	37	15	48
4	Early flowering of golden shower tree indicates increasing temperature	G	43	21	36
5	Earthworms coming out of the ground indicate good rainfall	H	35	19	46
6	Dragon fly flying low in groups indicates rainfall	I	25	46	29
7	Swarming of winged termites in the evening indicates rainfall	J	73	17	10
8	Ants transporting eggs to safer place indicate rainfall	K	46	37	17
9	Frogs croaking near swampy areas in groups indicate rainfall	V	37	45	18
10	Grey wagtail flying down to the earth in groups indicates rainfall	Y	49	20	31
11	Peacock making special sounds indicates rainfall	CC	67	24	9
12	Indian grey hornbill making noise indicates rainfall	DD	40	43	17
13	Jumping of cattle indicates rainfall	GG	28	23	49

Indigenous biotic indicators which were perceived as seldom reliable by majority of farmers are presented in Table 26. Twenty-two out of the thirty-five indicators had seldom reliability among majority of the farmers.

Percentage distribution of farmers based on reliability of each of the documented biotic indicators is given in the Figure 14. The results from the figure proved that, six indicators were reliable, three indicators were rated as sometimes reliable and 26 were seldom reliable. Most of the documented biotic indicators

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had only seldom reliability in the weather prediction due to changes in weather over time. The result was in accordance with the findings of Nganzi (2015).

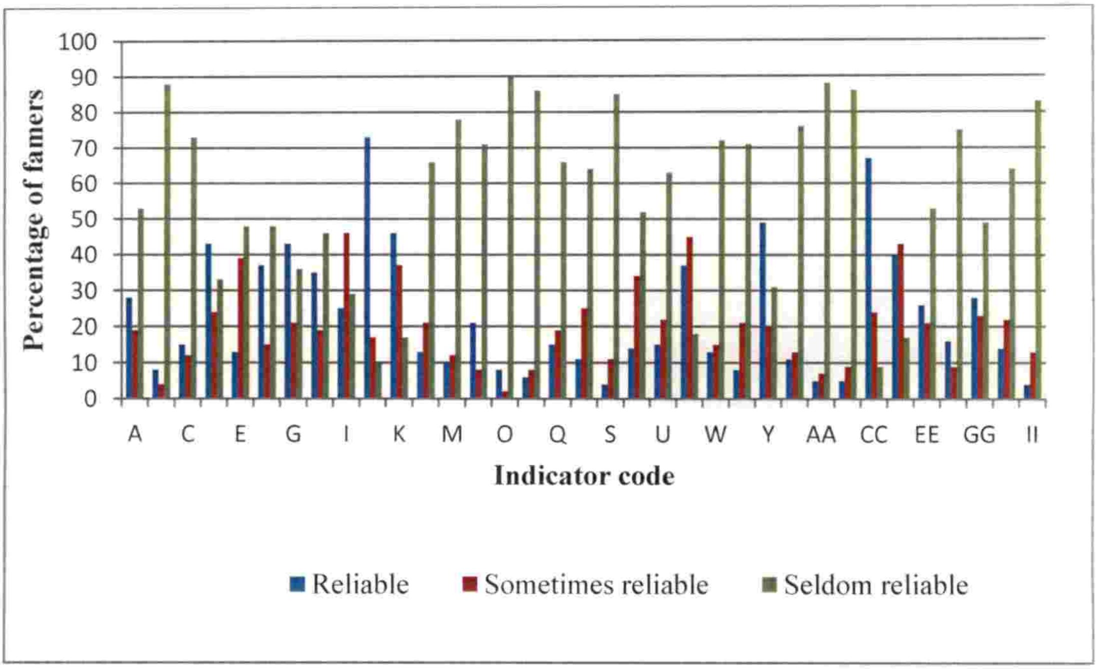

Figure. 14. Percentage distribution of farmers based on reliability of biotic indicators

Table 26. List of indigenous of indigenous biotic indicators for weather prediction with seldom reliability among farmers N= 100

Sl. No.	Indicator	Indicator code	Reliable	Sometimes reliable	Seldom reliable
			%	%	%
1	Heavy flowering of South Indian Plum indicates rainfall	A	28	19	53
2	Fully developed three seeds in the fruits of flame of forest indicate rainfall	B	8	4	88
3	Softening of stored flowers of illipe butter tree indicates rainfall	C	15	12	73
4	Cicada singing in groups indicates upcoming rain	L	13	21	66
5	Biting nature of housefly indicates rainfall	M	10	12	78
6	Honey bee hiding their honey comb and reduced bee activity indicate rainfall	N	21	8	71
7	Spider making thicker vertical webs relative to earth indicates rainfall	O	8	2	90
8	Crabs making sloppy holes in soil indicate rainfall	P	6	8	86
9	Appearance of large number of grasshoppers indicates upcoming rain	Q	15	19	66
10	Army worms seen in large numbers in paddy indicate no rainfall	R	11	25	64
11	Termite developing new hills indicates rainfall	S	4	11	85
12	Butterflies seen in large numbers indicate no rainfall	T	14	34	52
13	Emergence of fish swimming near the pond indicates good rainfall	U	15	22	63
14	Snakes seen in large numbers indicate good rainfall	W	13	15	72
15	Owl making special sounds indicates good rainfall	X	8	21	71
16	Eagle flying down to earth and making special noise indicate rainfall	Z	11	13	76
17	Unusual chirping of hill myna indicates rainfall	AA	5	7	88
18	Greater Coucal making special sounds indicates rainfall	BB	5	9	86
19	Chicken staying under shade and bathing in dust indicate rainfall	EE	26	21	53
20	Crows crying during the night indicate drought	FF	16	9	75
21	Unusual barking and restlessness of street dogs indicate rainfall	HH	14	22	64
22	Malabar giant squirrel seen in large numbers indicates no rainfall	II	4	13	83

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4. 3. 3. 4. Use Validity Score of biotic indicators based on farmers' perception

Documented ITKs were validated through farmer participatory process using Use Validity Score (UVS). The UVS of a particular ITK was measured as a function of three dimensions viz. purpose of use, extent of use and perceived reliability.

Indigenous biotic indicators with high UVS (>2.56) based on farmers' perception is given in Table 27. Out of the 35 biotic indicators documented, eight indicators had UVS > 2.56. They were swarming of winged termites, frogs croaking near swampy areas, grey wagtail flying down to the earth, dragon fly flying low in groups, Indian grey hornbill making noise, peacock making special sounds and chickens staying under shade and bathing in dust. All of these indicated rainfall and had the respective UVS scores of 3.03, 3.00, 2.92, 2.71, 2.69, 2.62 and 2.57. Early flowering of golden shower tree was the only indicator with high UVS of 2.67 that was used to predict dry weather. It indicated increase in temperature.

Table 27. Indigenous biotic indicators with high use validity (>2.56) based on farmers' perception N=100

Sl. No.	Indicator	Raw UVS	Weighted UVS
1	Swarming of winged termites in the evening indicates rainfall	8.94	3.03
2	Frogs croaking near swampy areas in groups indicate rainfall	8.87	3.00
3	Grey wagtail flying down to the earth in groups indicates rainfall	8.30	2.92
4	Dragon fly flying low in groups indicates rainfall	8.29	2.71
5	Indian grey hornbill making noise indicate rainfall	8.12	2.69
6	Early flowering of golden shower tree indicates increasing temperature	8.02	2.67
7	Peacock making special sounds indicates rainfall	7.76	2.62
8	Chicken staying under shade and bathing in dust indicate rainfall	7.68	2.57

Indigenous biotic indicators with medium UVS based on farmers' perception are given in Table 28. Twenty-one indicators had medium UVS scores that ranged between 1.43 and 2.56. These included softening of stored tamarind and flowers of illipe butter tree, ants transporting eggs into safer places, cicada singing in groups, grasshoppers seen in large numbers, reduced bee activity, biting nature of housefly, termite developing new hills, snake seen in large numbers, eagle flying down to earth, jumping of cattle, earthworm coming out of the ground, unusual barking and restlessness of dogs, emergence of fish swimming near the pond, owl making special noise, heavy flowering of south Indian plum. All of these were used to predict rainfall. Butterflies and army worms seen in large numbers, crows crying during night and flowering of night blooming jasmine were indicators with medium UVS but were used to predict dry season or no rainfall.

Indigenous biotic indicators with low UVS (< 1.43) based on farmers' perception is given as Table 29. Six indicators that had low UVS scores were the fully developed three seeds in flame of forest, spider making thicker vertical webs, unusual chirping of hill myna, greater coucal making special noise and crabs making sloppy holes in the soil. All these were related to the prediction of rainfall. However, presence of Malabar giant squirrel in large numbers which also had a low UVS score of 1.39 was related to low rainfall.

Table 28. Indigenous biotic indicators with medium use validity (between 1.43- 2.56) based on farmers' perception

Sl. No.	Indicator	Raw UVS	Weighted UVS
1	Softening of stored tamarind indicates rainfall	7.60	2.53
2	Ants transport eggs to safer place indicates rainfall	7.50	2.51
3	Jumping of cattle indicates rainfall	7.44	2.48
4	Butterflies seen in large numbers indicate no rainfall	6.58	2.21
5	Army worms seen in large numbers in paddy indicate no rainfall	6.30	2.13
6	Flowering of night blooming jasmine indicates onset of dry season	6.22	2.07
7	Earthworms come out of the ground indicate good rainfall	6.11	2.03
8	Unusual barking and restlessness of street dogs indicate rainfall	5.90	2.01
9	Emergence of fish swimming near the pond indicates good rainfall	5.86	1.98
10	Owl making special sounds indicates good rainfall	5.76	1.94
11	Heavy flowering of South Indian Plum indicates rainfall	5.74	1.92
12	Heavy flowering of mango tree indicates drought	5.60	1.82
13	Cicada singing in groups indicates upcoming rain	5.35	1.81
14	Appearance of large number of grasshoppers indicates upcoming rain	5.36	1.79
15	Snakes seen in large numbers indicate good rainfall	5.13	1.72
16	Honey bee hiding their honey comb and reduced bee activity indicate rainfall	4.98	1.65
17	Termite developing new hills indicates rainfall	4.80	1.63
18	Softening of stored flowers of illipe butter tree indicates rainfall	4.78	1.62
19	Biting nature of housefly indicates rainfall	4.60	1.61
20	Eagle flying down to earth and making special noise indicate rainfall	4.55	1.51
21	Crows crying during the night indicate drought	4.49	1.48

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Table 29. Indigenous biotic indicators with low use validity (<1.43) based on farmers' perception N= 100

Sl. No.	Indicator	Raw UVS	Weighted UVS
1	Malabar giant squirrel seen in large numbers indicates no rainfall	4.14	1.39
2	Crabs making sloppy holes in soil indicate rainfall	3.90	1.31
3	Greater coucal making special sounds indicates rainfall	3.80	1.26
4	Unusual chirping of hill myna indicates rainfall	3.73	1.24
5	Spider making thicker vertical webs relative to earth indicates rainfall	3.71	1.23
6	Fully developed three seeds in the fruits of flame of forest indicate rainfall	2.70	0.90

It can be inferred from the results that, most of the indicators had medium (21 no.) or high use validity (8 no.) among farmers. Indicators with high UVS were mostly based on observations of biological processes related to plants and animals. As the difficulty of observation increased in terms of requirement of specific details and skills, the popularity of indicator showed a decreasing trend towards medium to low levels.

4. 3. 4. Validation of biotic indicators based on published research findings

The documented biotic indicators were also validated based on thematic content analysis in relation to the existing theories and findings from scientific reports of research. The results of scientific thematic validation are presented.

4. 3. 4. 1 Scientifically validated biotic indicators for weather prediction

The validation using available theoretical explanations and findings from various published research sources identified four biotic indicators with valid scientific proof. However, most of the evaluated biotic indicators had only theoretical explanation and are presented in Table 30.

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Table 30. Scientifically validated biotic indicators for weather prediction

Sl. No.	Indicator	Reported state/ country	Similar indicator reported by	Reference
1. Indicators related prediction of rainfall				
1	Softening of stored flowers of illipe butter tree (*Madhuka nerifolia*)	Jharkhand	Kumar, 2004	ICAR, 2004
2	Softening of stored tamarind (*Tamarindus indica*)	Andhra Pradesh	Shankar *et al.*, 2008	ICAR, 2004
3	Ants transport eggs to safer place	Tripura	Acharya, 2011	ICAR, 2004
4	Spider webs makes thicker vertical webs relative to earth	Jharkhand	Kandulna , 2004	ICAR, 2004

The indicators presented in the table had verified scientific proof of the experiments published in the research report of ICAR (2004) and are given below.

a) Softening of stored flowers of illipe butter tree (*Madhuka nerifolia*) indicate rainfall

PRA and laboratory experiments were conducted to analyze the ITK. *Madhuka* flowers were identified to have hygroscopic properties. This was attributed to the presence of sugar which absorbs moisture from atmosphere in humid conditions. This was used as indicator of atmospheric wetness, and on this basis occurrence of rainfall could be predicted. Results obtained from PRA and laboratory experiment are in good agreement with each other.

b) Softening of stored tamarind fruits indicate rainfall

ICAR conducted both PRA and laboratory experiment to analyze the ITK. On the basis of results obtained from laboratory experiment, it was inferred that tamarind fruits have hygroscopic properties and could be used as an indicator of atmospheric wetness. This property correlated with the use of softening of stored tamarind in rainfall prediction by farmers.

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c) Ants transporting eggs to safer places indicating rainfall

Results of the ICAR (2014) report based on field study was used to validate the ITK. The study was conducted in four villages of Uttar Pradesh. The indicator was found to be reliable and valid, as observed in all the 12 case studies conducted.

f) Spider makes thicker vertical webs related to earth indicating onset of rains

ICAR (2014) field study report was used to validate the ITK. The study was carried out in Jharkhand. The study revealed that, percentage of vertically oriented spider webs increased with the passage of time from dry season to the onset of monsoon and remained at higher percent in the monsoon season. Based on this, it was inferred that the vertical orientation of majority of spider webs could be taken as an indication of onset of monsoon.

4. 3. 4. 2 Experientially validated biotic indicators by farmers

The biotic indicators which had no reported scientific proof or theoretical explanation but were popular among farmers are enlisted in Table 31. Out of the twenty listed indicators majority (12 no.) of the indicators came under this category. These indicators needed future research to check its rationality.

It could be observed that, only four indicators were scientifically validated out of 35 biotic indicators documented. However, the remaining 31 indicators had the experiential support of farmers and needed future research to check its scientific rationality. Therefore, it is recommended that, more in-depth studies need to be taken up on the scientific validity and accuracy of these ITKs. This will help to establish a more valid knowledge database that could be used to develop robust weather forecasting systems useful under climate change.

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Table 31. Biotic indicators reported as rational by farmers but without scientific proof

Sl. No.	Indicator	Similar indicator reported by
I. Indicators to predict rainfall		
1	Fully developed three seeds in the fruits of flame of forest	Shankar *et al.*, 2008; Acharya, 2011
2	Dragon fly flying low in groups	KAU, 2015; Acharya, 2011; Shankar *et al.*,2008
3	Swarming of winged termites/ black rainfly in the evening	KAU, 2015
4	Cicada singing in groups indicates upcoming rain	KAU, 2015; Joshua *et al.*, 2011
5	Heavy flowering of south Indian plum	-------
6	Earthworms coming out of the ground in rainy season ensures good rain in the particular day	Sethi *et al.*, 2011
7	Biting nature of housefly	Shankar *et al.*, 2008.
8	Grasshoppers seen in large number indicate rainfall	KAU, 2015
9	Crabs making sloppy holes in soil ensures good rainfall	KAU, 2015
10	Termites developing new mounts	------
11	Frogs croaking near swampy areas in groups	Shankar *et al.*, 2008.; Sethi, *et al.*, 2011; Chengula and Nyambo, 2016
12	Presence of large number of snakes indicates good rainfall	KAU, 2015; Jiri, *et al.*, 2016
13	Jungle owlet making special sounds indicates upcoming rainfall	KAU, 2015; Acharya, 2011; Shankar *et al.*,2008
14	Grey wagtail flying down to the earth in groups	KAU, 2015

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Continued...

15	Eagle makes special sounds and flies low	KAU, 2015
16	Unusual chirping of Hill myna and aggressive behaviour	Acharya, 2011
17	Greater Coucal making special sounds	--------
18	Peacock making special sounds and make rhythmic movements	Acharya, 2011
19	Indian grey hornbill make noise	KAU, 2015
20	Chicken staying under shade and bathing in dust indicate upcoming rain	KAU, 2015; Acharya, 2011
21	Jumping of cattle	Shankar *et al.*, 2008
22	Emergence of fish swimming near the surface of pond	Barayazarra and Puri, 2011
23	Unusual barking and restlessness of dogs	------
II. indicators to predict onset of dry season/ no rainfall		
24	Heavy flowering of wild mango tree	Joshua *et al.*, 2011
25	Early flowering of golden shower tree	KAU, 2015
26	Flowering of Night blooming jasmine indicates onset of dry season	------
27	Butterflies (white colour) seen in large numbers indicate no rainfall	KAU, 2015
28	Honey bee hiding their honey comb and reduced bee activity	-------
29	Army worms seen in large numbers in paddy indicate dry period	Jiri *et al.*, 2016
30	Crows crying during night	-------
31	Malabar giant squirrel seen in large numbers	KAU, 2015

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4. 4 Scope of validated ITKs in local crop weather forecast based on farmer perception

The scope of validated ITKs in local crop weather forecast was done using UVS scores. The abiotic indicators in local crop weather forecast were validated and their scope is given in Table 32. Abiotic indicators with high UVS in the order of ranks were, clear blue sky related to no rainfall (3.33, Rank 1) followed by thunder and lightning with UVS 3.15 (Rank 2) and dark rolling clouds along with cool breeze (2.94, Rank 3) both related to imminent rainfall. The top ranked indicators were based on generalized observation of natural features.

The scope of validated biotic indicators in local crop weather forecast is given in Table 33. Among biotic indicators, all the three top ranked indicators were used for the prediction of rains and were associated with swarming of winged termites in the evening (Rank 1), frogs croaking near swampy areas in groups (Rank 2) and grey wagtail fly down to the earth in groups (Rank 3) with UVS 3.03, 3.00, 2.92 respectively.

The indicators with top ranks were mostly based on general observations of common natural features. As the difficulty of observation increased in terms of requirement of specific details, the ranks of indicators showed a decreasing trend. The low ranked indicators needed more skills and techniques to analyze the weather. Even though the low ranked indicators are potent in weather prediction, the popularity of the same is limited among farmers. Integrating these indicators with formal sources may help to popularize and increase the adaptability among farmers.

Table 32. Scope of validated abiotic indicators in local crop weather forecast

Sl. No.	Indicator	Weighted UVS	Rank
1	Clear blue sky indicates no rainfall	3.33	Rank 1
2	Thunder and lightning indicate upcoming rainfall	3.15	Rank 2
3	Dark rolling clouds along with cool breeze indicates rainfall	2.94	Rank 3
4	Clear moon and stars indicate no rainfall	2.83	Rank 4
5	Cool breeze along with moisture indicates rainfall	2.75	Rank 5
6	Reduction in water level in swamps, lagoons and *Kenies* indicates drought	2.60	Rank 6
7	Thunderstorm in April- May is associated with hailstones and heavy rainfall	2.39	Rank 7
8	Drop in temperature at night / coldness at night indicates onset of dry season/ no rain	2.38	Rank 8
9	Dense fog in early morning indicates no rainfall	2.27	Rank 9
10	Unusual increased temperature during day and night indicates rainfall	2.24	Rank 10
11	Rainbow in the western sky indicates rainfall	2.07	Rank 11
12	Red sky indicates no rainfall	2.03	Rank 12
13	Red clouds indicate no rainfall	1.87	Rank 13
14	Halo around the moon, indicates good rainfall	1.86	Rank 14
15	Warm breeze along in February- March indicates rainfall	1.81	Rank 15
16	Clouds with vertical development are associated with thunderstorm, lighting and heavy rainfall	1.73	Rank 16
17	Rainbow in the east direction, indicates absence of rain/ less rainfall	1.61	Rank 17
18	Widespread cloud cover is associated with lighter showers on and off over several hours	1.35	Rank 18
19	Whirlwinds or dust devils are clear indication of onset of dry seasons	1.28	Rank 19
20	Occurrence of rain in presence of sunshine indicates absence of rain in near future	1.17	Rank 20

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Table 33. Scope of validated biotic indicators in local crop weather forecast

Sl. No.	Indicator	Weighted UVS	Rank
1	Swarming of winged termites in the evening indicates rainfall	3.03	Rank 1
2	Frogs croaking near swampy areas in groups indicate rainfall	3.00	Rank 2
3	Grey wagtail flying down to the earth in groups indicates rainfall	2.92	Rank 3
4	Dragon fly flying low in groups indicates rainfall	2.71	Rank 4
5	Indian grey hornbill making noise indicates rainfall	2.69	Rank 5
6	Early flowering of golden shower tree indicates increasing temperature	2.67	Rank 6
7	Peacock making special sounds indicates rainfall	2.62	Rank 7
8	Chicken staying under shade and bathing in dust indicate rainfall	2.57	Rank 8
9	Softening of stored tamarind indicates rainfall	2.53	Rank 9
10	Ants transport eggs to safer place indicates rainfall	2.51	Rank 10
11	Jumping of cattle indicates rainfall	2.48	Rank 11
12	Butterflies seen in large numbers indicate no rainfall	2.21	Rank 12
13	Army worms seen in large numbers in paddy indicate no rainfall	2.13	Rank 13
14	Flowering of night blooming jasmine indicates onset of dry season	2.07	Rank 14
15	Earthworms coming out of the ground indicate good rainfall	2.03	Rank 15
16	Unusual barking and restlessness of street dogs indicate rainfall	2.01	Rank 16

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17	Emergence of fish swimming near the pond indicates good rainfall	1.98	Rank 17
18	Owl making special sounds indicates good rainfall	1.94	Rank 18
19	Heavy flowering of South Indian Plum indicates rainfall	1.92	Rank 19
20	Heavy flowering of mango tree indicates drought	1.82	Rank 20
21	Cicada singing in groups indicates upcoming rain	1.81	Rank21
22	Appearance of large number of grasshoppers indicates upcoming rain	1.79	Rank 22
23	Snakes seen in large numbers indicate good rainfall	1.72	Rank 23
24	Honey bee hiding their honey comb and reduced bee activity indicate rainfall	1.65	Rank 24
25	Termite developing new hills indicates rainfall	1.63	Rank 25
26	Softening of stored flowers of illipe butter tree indicates rainfall	1.62	Rank 26
27	Biting nature of housefly indicates rainfall	1.61	Rank 27
28	Eagle flying down to earth and making special noise indicate rainfall	1.51	Rank 28
29	Crows crying during the night indicate drought	1.48	Rank 29
30	Malabar giant squirrel seen in large numbers indicates no rainfall	1.39	Rank 30
31	Crabs making sloppy holes in soil indicate rainfall	1.31	Rank 31
32	Greater coucal making special sounds indicate rainfall	1.26	Rank 32
33	Unusual chirping of hill myna indicates rainfall	1.24	Rank 33
34	Spider making thicker vertical webs relative to earth indicates rainfall	1.23	Rank 34
35	Fully developed three seeds in the fruits of flame of forest indicate rainfall	0.90	Rank 35

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4. 5 Accessibility and perceived reliability of weather forecast from agricultural department and IMD by farmers

The results of the accessibility of weather forecast services to farmers of the selected panchayats ie. Padinjarethara, Vellamunda, Nenmeni and Mullankolly of Wayanad district and their perception about the reliability of weather forecast information from formal sources are presented.

Agro-met information services of agriculture department in the selected panchayats revealed that, they were in the stages of infancy. Informal discussions with the service provider staff of the department indicated that, at present, they are not providing any weather services to the farmers residing in the selected panchayats as well as to the whole district due to the lack of permanent agro meteorologist.

The information from service provider staff revealed that, the weather forecast services were not available to farmers since around 2013. During that time, agricultural department used mass media such as television (TV), Newspapers and social networking sites for disseminating weather services to farmers.

They had created a "WhatsApp group" named "Njattadi". WhatsApp is a free internet based messaging app available in smart phones. Even though, the application is not an agro-met service, it acted as a channel for communication. The WhatsApp group included agricultural officers and farmers. Njattadi served as a social platform for the farmers to clarify their doubts and to gain information regarding the weather. Apart from this, agro- met advisories were also disseminated through Wayanad vision TV channel and through Newspapers.

Currently the farmers were not accessible to any formal weather forecast information. Radio and TV forecasts were the only formal sources available, but had only limited perceived reliability. Hence, farmers make decisions based on their personal competence, which means farmer's knowledge of weather forecasting learned through many years of own experience of local climatic patterns. In the absence of formal meteorological forecast, farmers relied on ITKs for weather prediction.

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SUMMARY

CHAPTER 5

SUMMARY

The present study focused on the documentation and validation of biotic and abiotic indicators used by farmers for weather prediction in Wayanad District, Kerala. The objectives of the study were to document ITKs based on biotic and abiotic indicators used by farmers in weather prediction and to validate and assess the documented ITKs through farmer participatory processes and published research findings. It also aimed to rank and evaluate the scope of validated ITKs in local crop weather forecast based on farmer perception. The accessibility and perceived reliability of weather forecast from agricultural department and IMD by farmers were also undertaken.

The study was conducted in Padinharethara, Vellamunda, Nenmeni and Mullankolly panchayats of Wayanad. The survey of the study area was conducted in the months of December 2017- February, 2018. Data were collected from a sample of 100 randomly selected farmers. Personal interview method using pre-tested open ended interview schedule was used to collect data from the selected sample farmers. In addition, 20 key informants were purposively selected for documenting ITKs used in weather prediction. In order to ensure the collection of meaningful information, participatory tools like FGD were used involving expert farmers/ key informants and irrelevant and irrational practices were screened off.

The documented ITKs were validated through farmer participatory process using Use Validity Score (UVS) and published research findings. The ranking of the documented ITKs were also done using UVS.

5. 1. Salient findings of the study

The salient findings are summarised below:

Profile characteristics

1. Majority (63%) of the farmers belonged to old age category (above 50 years) and 51 per cent of the farmers had educational qualification up to high school level.

2. Majority (73%) of the respondents were having more than 25 years of experience in farming.
3. Majority of the farmers (56%) had farm size above 1.50 ha which comes under small holding size.
4. Agricultural labourers who had farming as a subsidiary vocation comprised of 28 per cent of the respondents and average annual income of farmers was Rs.2.66 lakhs.
5. Majority (49%) of respondents were members in at least one organization.
6. Majority (28%) of the farmers practiced rice-vegetables cropping pattern followed by coffee- arecanut- pepper (21%). The mean score of 3.18 revealed coffee- arecanut- pepper cropping system was the predominant type.

Documentation of indicators

1. Twenty abiotic and 35 biotic indicators were documented.
2. Most of the documented indicators were related to prediction of rains.

Validation and ranking of documented indicators

1. Four abiotic indicators and 8 biotic indicators had high UVS among farmers.
2. Among abiotic indicators, clear blue sky indicating no rainfall ranked 1 with 3.33 UVS, thunder and lightning indicating rainfall became rank 2 with 3.15 UVS and dark rolling clouds along with cool breeze indicating rainfall ranked 3rd with UVS 2.94.
3. Among biotic indicators, swarming of winged termites in the evening indicating rainfall was ranked one with 3.03 UVS. This was followed by frogs croaking near swampy areas in groups indicating rainfall ranked second with 3.00 UVS and grey wagtail flying down to the earth in groups indicating rainfall ranked at 3rd position with UVS 2.92.
4. Eight, out of 20 abiotic indicators and four out of 35 biotic indicators were scientifically validated using published reseach results and theory.

Accessibility and perceived reliability of weather forecast from agricultural department and IMD by farmers

1. At present farmers, had very limited access to any formal meteorological forecasts. The weekly forecasts were available only on department websites and no direct sourcing of these information to farmers was available. Hence, farmers mostly depended on their personal competence, and traditional wisdom of weather forecasting learned through many years of own experience of local climatic patterns. In the absence of formal meteorological forecast, farmers relied on ITKs for weather prediction.
2. Radio and TV forecasts were the only formal sources available, but had only limited perceived reliability among farmers.

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APPENDIX

APPENDIX - 1

KERALA AGRICULTURAL UNIVERSITY

ACADEMY OF CLIMATE CHANGE EDUCATION AND RESEARCH, VELLANIKARA, THRISSUR

"Documentation and validation of biotic and abiotic indicators used by farmers for weather prediction in Wayanad District, Kerala"

Block :
Respondent no:
Date :

INTERVIEW GUIDE

PART - I

1. Name : :
2. Address :
3. Name of the village :
4. Gender : Male/Female
5. Age :
6. Type of Farmer : Tribal / Non-Tribal
7. Land ownership status : Marginal/ Small/ Large
8. Farming experience (years) :
9. Area under cultivation :
10. Major crops cultivated :
11. Cropping pattern :
12. Education : Illiterate/LP/UP/HS/Degree
13. Economic Status : BPL/APL
14. Major occupation :

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PART II

Abiotic indicators for weather prediction

Sl no.	Indicator	Purpose of Use (PU)				Extend of Use (EU)						Perceived Reliability (PR)		
						Regularity of Use			Time of Use					
		SRF	MRF	LRF	Non-users	Regular use	Occasional use	Heard but seldom used	Throughout the year	Seasonal	Sporadic	Reliable	Sometimes Reliable	Seldom reliable
A	**Indicators related to clouds**													
1	Dark rolling clouds along with cool breeze indicate heavy rainfall													
2	Red clouds indicate no rainfall													
3	Clouds with vertical development are associated with thunderstorm, lightning and heavy rainfall													
4	Widespread cloud cover is associated with lighter showers on and off over several hours													
B	**Indicators related to sky**													
5	Red sky indicates no rainfall													
6	Clear blue sky indicates no rainfall													
C	**Indicators related to moon**													
7	Clear moon and clear stars indicate no rainfall													
8	Halo around the moon, indicates good rainfall													
D	**Indicators related to wind**													
9	Cool breeze along with moisture indicate rainfall													

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10	Warm breeze along in February- March indicates upcoming rain													
11	Whirlwinds or dust devils are clear indications of onset of dry seasons													
E	**Indicators related to fog**													
12	Dense fog in early morning indicates no rainfall													
F	**Indicators related to thunder and lightning**													
13	Thunder and lightning indicate upcoming rain													
14	Thunderstorm in April- May is associated with hailstones and heavy rainfall													
G	**Indicators related to rainbow**													
15	Rainbow in the west during S-W monsoon indicates upcoming rain													
16	Rainbow in the east direction, indicates absence of rain/ less rainfall													
H	**Indicators related to temperature**													
17	Drop in temperature at night/ coldness at night indicates onset of dry season/ no rain													
18	Unusual increased temperature during day and night especially in March indicates onset of rain													
I	**Indicators related to water level in open water bodies and rainfall**													
19	Reduction in water level in swamps,lagoons and *Kenies* indicates drought													
20	Occurrence of rain in presence of sunshine indicates absence of rain in near future													

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PART III

Biotic indicators for weather prediction

Sl no.	Indicator	Purpose of Use (PU)				Extend of Use (EU)						Perceived Reliability (PR)		
						Regularity of Use			Time of Use					
		SRF	MRF	LRF	Non-users	Regular	Occasiona	Heard but seldo	Throughout	Seasonal	Sporadic	Reliable	Sometimes Relia	Seldom reliable
A	**Indicators related to plants**													
1	Heavy flowering of South Indian Plum indicates good rainfall													
2	Fully developed three seeds in the fruits of Flame of Forest indicate good rainfall with uniform distribution throughout the season													
3	Softening of stored flowers of Illipe butter tree indicates rainfall													
4	Softening of stored tamarind indicates upcoming rain													
5	Heavy flowering of mango tree indicates drought													
6	Flowering of night blooming jasmine indicates onset of dry season													
7	Early flowering of Golden shower tree indicates increasing temperature													
B	**Invertebrate animal indicators used in weather prediction**													
a.	**Indicators related to annelids**													
1	Earthworms coming out of the ground in rainy season ensure good rain in the particular day													
b.	**Indicators related to insects**													

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1	Dragon fly flying low in groups indicates upcoming rain													
2	Swarming of winged termites/ black rainfly in the evening indicates upcoming rain													
3	Ants transporting eggs to safer place indicate upcoming rain													
4	Cicada singing in groups indicates upcoming rain													
5	Biting nature of housefly indicates upcoming rain													
6	Honey bee hiding their honey comb and reduced bee activity indicate upcoming rain													
7	Spider making thicker vertical webs relative to earth indicates upcoming rain													
8	Crabs making sloppy holes in soil indicate upcoming rain													
9	Appearance of large number of grasshoppers indicates upcoming rain													
10	Presence of Army worms in large numbers in paddy indicates upcoming rain													
11	Termites developing new mounts indicate upcoming rain													
12	Butterflies (white colour) seen in large numbers indicate upcoming rain													
C	**Vertebrates animal indicators used in weather prediction**													
a.	**Indicator related to fish**													
1	Emergence of fish swimming near the surface of pond indicates upcoming rain													
b.	**Indicator related to amphibians**													

2	Frogs croaking near swampy areas in groups indicate upcoming rain												
c.	**Indicator related to reptiles**												
3	Large number of snakes indicate upcoming rain												
d.	**Indicator related to birds**												
1	Jungle owlet making special sounds indicates upcoming rain												
2	Grey wagtail flying down to the earth in groups indicates upcoming rain												
3	Eagle making special sounds and flying low indicates upcoming rain												
4	Unusual chirping of Hill myna and aggressive behaviour indicate upcoming rain												
5	Greater Coucal making special sounds indicates upcoming rain												
6	Peacock making special sounds and making rhythmic movements indicates upcoming rain												
7	Indian grey hornbill making noise indicates upcoming rain												
8	Chicken staying under shade and bathing in dust indicate upcoming rain												
9	Crows crying during the night indicate adverse weather condition												
e.	**Indicator related to mammals**												
1	Jumping of cattle indicates upcoming rain												
2	Unusual barking and restlessness of street dogs indicate upcoming rain												
3	Malabar giant squirrel seen in large numbers indicate no rainfall												

PART IV

1. **Are you aware of meteorological forecasting?**

2. **Are you accessible to meteorological forecast from Agricultural Department or IMD?**

3. **How you are getting access to different weather forecast services? TV/ Mobile/Newspaper/ Radio**

4. **What is your opinion about the reliability of the weather forecasting services?**

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APPENDIX – 2

Cropped area and crop loss details, Wayanad (2015, 2016, 2017)

Cropped Area (2015-2016) **(Area in Hectors)**

Block	Paddy	Vegetables	Coconut	Arecanut	Coffee	Tea	Cardomom	Ginger	Turmeric	Pepper	Rubber	Tapioca	Banana	Tubers
Mananthavady Block														
Thavinjal	625	400	150	200	1250	2000	25	160	30	1400	300	100	400	125
Thirunelly	480	35	90	110	1600	0.8	0.4	35	8	750	10	40	150	20
Mananthavady	720	120	240	400	1526	1600	4	160	15	1400	430	300	690	300
Thondernadu	260	220	170	775	1450	1550	80	75	25	700	250	100	400	50
Edavaka	546	140	350	300	705	5	1	30	25	800	280	200	400	90
Vellamunda	490	100	400	550	1200	10	2	80	15	610	180	112	600	125
Kalpetta Block														
Padinjarethara	275	80	140	340	1453	2	5	95	15	320	250	150	610	125
Pozhuthana	14	20	100	130	1250	1290	384	30	10	520	5	15	614	10
Vengapally	85	75	130	120	700	0	5	50	5	210	60	60	300	100
Kalpetta	12	20	100	130	1130	304	10	35	2	150	15	5	180	42

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Meppady	117.9	125	325	100	950	2575	400	50	10	450	50	20	325	50
Kottathara	328	20	170	350	1000	0	5	50	20	100	200	35	300	45
Muttil	355	60	190	400	1520	0	10	100	10	250	15	60	500	120
Moopainad	5	35	143	487	1985	1205	62	85	15	926	21	73	215	110
Vythiri	0	16	70	400	1375	875	16	30	4	775	8	12	66	10
Thariode	27	25	200	180	1000	0	25	50	15	150	75	30	500	25
Sulthan bathery Block														
Sulthanbathery	700	30	400	700	1750	8	5	150	20	1350	300	100	400	50
Noolpuzha	1190	25	300	250	2900	1.05	1	300	10	1200	30	40	150	20
Meenangady	700	90	350	595	900	0	5	105	5	750	275	160	325	75
Ambalavayal	144	89	105	700	1640	130	5	100	20	1300	75	65	435	45
Nenmeni	1007	85	725	518	1200	400	5	300	5	1550	100	90	240	35
Panamaram Block														
Panamaram	1250	125	225	175	1800	0	0	200	5	1100	200	40	295	40
Mullenkolly	410	10	450	200	320	8	2	250	15	3500	250	10	100	50
Pulpally	560	225	900	400	600	0	2	700	20	3500	750	5	75	100
Poothady	700	30	450	250	2600	0	0	150	50	2500	150	150	450	100
Kaniyambeta	640	175	125	350	1160	0	18	80	22	715	93	54	520	57

* Principal agricultural office, Wayanad

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Cropped Area (2016-2017) **(Area in Hectors)**

Block	Paddy	Vegetabl es	Coconut	Arecanut	Coffee	Tea	Cardomo m	Ginger	Turmeric	Pepper	Rubber	Tapioca	Banana	Tubers
Mananthavady Block														
Thavinjal	625	400	150	200	1250	2000	25	160	30	1400	300	100	400	125
Thirunelly	720	125	150	110	2100	0	0	65	10	800	10	50	50	20
Mananthavady	720	120	240	400	1526	1600	4	160	15	1400	430	300	690	300
Thondernadu	260	220	170	775	1450	1550	80	75	25	700	250	100	400	50
Edavaka	546	140	350	300	705	5	1	30	25	800	280	200	400	90
Vellamunda	490	100	400	550	1200	10	2	80	15	610	180	112	600	125
Kalpetta Block														
Padinjarethara	400	30	140	340	1453	2	12	75	7	175	475	150	610	125
Pozhuthana	18	20	100	130	1250	1290	384	30	10	520	5	15	614	10
Vengapally	88	60	150	150	700	0	5	60	5	85	10	75	275	50
Kalpetta	14	14	70	130	1430	300	10	35	1	250	15	10	50	20
Meppady	117.9	125	325	100	950	2575	400	50	10	450	50	20	325	50
Kottathara	328	20	170	350	1000	0	5	50	20	100	200	35	300	45

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Muttil	355	60	190	400	1520	0	10	100	10	250	15	60	500	120
Moopainad	5	35	143	487	1985	1205	62	85	15	926	21	73	215	110
Vythiri	0	5	65	420	1375	875	168	11	5	750	8	10	60	10
Thariode	29	20	180	150	600	0	25	30	15	50	75	30	400	25
Sulthan bathery Block														
Sulthanbathery	700	30	400	700	1750	8	5	150	20	1350	300	100	400	50
Noolpuzha	1190	25	300	250	2900	1.05	1	300	10	1200	30	40	150	20
Meenangady	700	90	350	595	900	0	5	105	5	750	275	160	325	75
Ambalavayal	144	89	105	700	1640	130	5	100	20	1300	75	65	435	45
Nenmeni	1007	85	725	518	1200	400	5	300	5	1550	100	90	240	35
Panamaram Block														
Panamaram	1250	125	225	175	1800	0	0	200	5	1100	200	40	295	40
Mullenkolly	410	10	450	200	320	8	2	250	15	3500	250	10	100	50
Pulpally	560	225	900	400	600	0	2	700	20	3500	750	5	75	100
Poothady	700	30	450	250	2600	0	0	150	50	2500	150	150	450	100
Kaniyambeta	640	175	125	350	1160	0	18	80	22	715	93	54	520	57

* Principal agricultural office, Wayanad

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Crop loss under natural calamity (2015-2016) **(Area in Cents)**

Block	Paddy	Banana	Coconut	Arecanut	Pepper	Coffee	Tea	Plantain	Vegetables
Mananthavady Block									
Thavinjal	30	1000	-	100	-	-	-	-	270
Thirunelly	850	1010	-	15	200	1000	-	-	20
Mananthavady	-	490	-	65	-	-	-	-	200
Thondernadu	-	670	-	65	-	-	-	-	160
Edavaka	150	785	-	100	-	-	-	-	400
Vellamunda	250	590	-	30	-	-	-	-	355
Kalpetta Block									
Padinjarethara	50	2800	-	302	-			21	100
Pozhuthana	-	125	-	30	-	-	-	1	-
Vengapally	-	726	-	50	-	-	-	50	-
Kalpetta	25	710	80	60	5	-	-	-	-
Meppady	15	750	5	-	-	-	-	-	-
Kottathara	15	345	11	280	-	-	-	50	-

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Muttil	5	353	6	150	-	-	-	70	-
Moopainad	-	405	65	150	90	-	-	115	-
Vythiri		530	16	49	15	-	-	20	-
Thariode		-	-	-	-	-	-	-	-
Sulthan bathery Block									
Sulthanbathery	-	612	8	28	-	-	-	27	-
Noolpuzha	50	450	-	-	-	-	-	50	-
Meenangady	150	1050	-	-	-	-	-	-	-
Ambalavayal	10	700	5	5	-	10	-	-	2
Nenmeni	-	1000	-	20	-	-	-	50	-
Panamaram Block									
Panamaram	35	680	-	50	-	-	-	-	190
Mullenkolly	40	345	50	70	415	300	-	50	-
Pulpally	20	925	7	37	20	-	-	-	-
Poothady	50	1250	6	20	-	-	-	10	-
Kaniyambeta	-	1445	-	20	-	-	-	75	-

*Source: District office of Economics and Statistics Wayanad

Crop loss under natural calamity (2016-2017) **(Area in Cents)**

Block	Paddy	Banana	Coconut	Arecanut	Pepper	Coffee	Tea	Plantain	Vegetables
Mananthavady Block									
Thavinjal	10000	-	-	-	-	-	-	-	-
Thirunelly	2220	763	25	34	10	-	-	2	-
Mananthavady		700	-	-	-	-	-	-	-
Thondernadu	450	6825	-	-	150	-	-	-	-
Edavaka	600	3200	-	-	-	-	-	2	-
Vellamunda	100	6725	-	-	-	-	-	-	-
Kalpetta Block									
Padinjarethara	2500	190	10	5	-	-	-	-	-
Pozhuthana	20	130	-	10	-	-	-	-	-
Vengapally	27	165	-	10	-	-	-	-	-
Kalpetta	65	105	10	15	-	-	-	10	25
Meppady	350	30	8	56	-	-	-	-	-
Kottathara	455	120	-	55	-	-	-	-	-
Muttil	-	70	70	87	-	-	-	-	-

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Moopainad	-	35	20	105	10	-	-	-	-
Vythiri	100	80	14	28	-	-	-	-	-
Thariode	-	-	-	-	-	-	-	-	-
Sulthan bathery Block									
Sulthanbathery	100	250	-	-	-	-	-	-	-
Noolpuzha	3212	370	70	35	100	-	-	100	5
Meenangady	700	50	-	-	-	-	-	-	-
Ambalavayal	400	250	25	150	-	-	-	-	-
Nenmeni	2100	450	-	50	-	-	50	-	-
									-
Panamaram Block									
Panamaram	800	1000	40	25	200	210	-	-	-
Mullenkolly	1200	362	200	650	2550	2150	-	-	50
Pulpally	725	100	-	40	150	-	-	-	-
Poothady	1650	300	-	20	150	40	-	50	-
Kaniyambeta	730	410	6	40	-	-	-	25	-

*Source: District office of Economics and Statistics Wayanad

DOCUMENTATION AND VALIDATION OF BIOTIC AND ABIOTIC INDICATORS USED BY FARMERS FOR WEATHER PREDICTION IN WAYANAD DISTRICT, KERALA

by

ANJU R

2013-20-103

ABSTRACT

Submitted in partial fulfillment of the

requirement for the degree of

BSc-MSc (Integrated) CLIMATE CHANGE ADAPTATION

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ACADEMY OF CLIMATE CHANGE EDUCATION AND RESEARCH

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

2018

ABSTRACT

Indigenous Technical Knowledge (ITK) is an integral part of the culture and history of a local community. It is evolved through many years of regular experimentation on the day to day life and resources available in the community. Biotic and abiotic indicators used by farmers for weather prediction are the parts of the ITK. Twenty abiotic indicators and thirty-five biotic indicators were documented in this study. The documented indicators were validated through farmer participatory process using Use Validity Score (UVS) and through published research findings. Based on UVS, four abiotic and eight biotic indicators could be grouped under high UVS category (>2.80 and > 2.56 respectively). The abiotic indicators with high UVS were mostly based on general observations of common natural features. As the difficulty of observation increased in terms of requirement of specific details, the popularity of indicators showed a decreasing trend towards medium to low levels. Abiotic indicators with high UVS in the order of ranks were clear blue sky related to no rainfall (3.33 UVS) followed by thunder and lightning with UVS 3.15 and dark rolling clouds along with cool breeze (2.94), both related to imminent rainfall. Among biotic indicators, all the three top ranked indicators were used for the prediction of rains and were associated with swarming of winged termites in the evening, frogs croaking near swampy areas in groups and grey wagtail flying down to the earth in groups with UVS 3.03, 3.00 and 2.92 respectively. Thematic content analysis based on published theories and related research validated eight abiotic and four biotic indicators scientifically. Most important inference from the study was that, people still relied on ITKs for weather prediction and were depended on simple observations related to common natural features. Moreover, the farmers' access to formal meteorological forecasts was limited to mass media sources. Customized crop-based weather forecast that promotes integrated use of popular ITKs, can improve the efficiency and reliability of the weather forecast among farmers.