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# Association of biotic factors with indigenous knowledge of farmers on rainfall predictions

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Farmers use different factors (biotic and abiotic) around them to predict rainfall. Several Indigenous Technical Knowledge (ITK) practices followed by farmers in different parts of the country are documented and published. ITKs collected from flood and drought prone areas of south India along with documented ITKs were analysed to know the biotic indicators used by farmers to predict rainfall. These biotic factors were classified as insects, birds and animals. Farmers use 19 types of insects, 17 types of birds and 10 types of animals as indicators to predict rainfall. Various behaviour types of these biotic factors are observed by farmers based on which they make decisions about possibility of rain occurring and in some cases the intensity of rain. These are grassroots innovations which are time tested and facilitated farmers to make their farming decisions.

**Keywords**: Animals, Behaviour, Birds, Forecast, Indigenous knowledge, Insects

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Climate change first became news in 1988 when Intergovernmental Panel on Climate Change (IPCC) was established due to alarming accumulation of green house gas emissions resulting into unprecedented environmental changes. Increased human intervention in green house gas emissions was the reason behind it. As a result, frequent drought, flood, shift in rainfall pattern and seasons etc became regular phenomena that pushed international community to form IPCC exclusively to address the issue of climate change at global level. But way before that, farmers of tropical countries were experiencing drought and floods and adjusting their farming practices according to change in weather parameters. Their concerns of subjecting farming to climate variations before 1988 were neither raised by these voiceless community and nor heard/thought by government agencies. Its only when whole lot of urban population mainly those living in developed countries started getting affected with changes in climate, formation of IPCC took place.

Weather forecasting is one of the important components to address climate change related issues. It is a way of predicting things like cloud cover, rain, snow, wind speed and temperature before they happen. Many instruments such as barometers, radar thermometers are used to develop computer models to process data accumulated from these instruments. Reliable weather predictions specific to particular agro-ecological zones is still remains a challenge in diverse country like India. However, to this day, humans with good experience can still do a better job at predicting the weather than computer models alone[1]. Unlike others, farmers are not simply passive victims of environmental hazards and climate change[2]. They have developed indigenous resilience and developed capacities to cope and respond to changing environmental conditions over millennia. Farmers have accumulated knowledge about different dimensions of farming by observations and experiential learning. Practicing farmers have a wide array of knowledge; current and traditional, related to climate change impacts[3]. As farming in tropics is extremely weather sensitive and depends heavily on it, one can find farmers using lot of things around them to predict weather. Even after robust communication network and availability of weather predictions from public agencies, farmers continue to rely on local knowledge to decide how the monsoon in the coming season is

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going to be and accordingly plan their crop production activities. The local knowledge accumulated over generations is indeed a time tested phenomena but as mentioned earlier behaves dynamically. Their capacity to generate and apply knowledge and not the knowledge itself to various dimensions of farming contributed to their resilience of the system. Their indigenous knowledge is flexible and dynamic continually being updated and reviewed. For this they use different systems of classification including biota and bio-physical conditions.

Among different weather parameters like temperature, humidity, sunlight duration/day length its the rainfall that matters apparently the most in farming. Success of farming is measured by farmers mainly on amount and distribution of rainfall in a crop season. So, farmers' knowledge on predicting rainfall outweighs than temperature and other climatic parameters. Farmers make use of various factors like atmosphere condition, astronomic and relief features, behaviour of botanicals and animals to predict rainfall. Many ITKs are documented and published on rainfall predictions. Perusal of these ITKs amazed the researchers about the variety of indicators used and similarity/differences in these indicators across regions and zones despite India being ecologically very diverse. So, an analysis of ITKs (documented and collected for the study) was done to know- what types of indicators farmers use to predict rainfall and which are the ITKs that are commonly found or otherwise in different regions of the country. Wherever possible, scientific reasons for use of specific indicators are elaborated in the paper.

## Methodology

### Data sources

All the available published literature encompassing various resources was perused and those relevant to Indian conditions were pulled out. Besides, ITKs were collected from four villages of Haveri district (drought prone area) and four villages of Belgaum district (flood prone area) of Karnataka located in southern part of India. For collecting ITKs, facilitators of state agriculture department who work at village level and most of them basically hail from villages were contacted. They were briefed about the purpose of the study. With their help, group discussions in each selected village were organized. Only those farmers who are above 50 years were involved in the group discussions. These discussions were guided by checklists and ITKs emerged in discussions were documented. Approximately 25 farmers in each group (village) participated in the discussions. So across 8 villages around 200 farmers were part of the discussions. Nearly 250 ITKs were screened for weather predictions. Only those ITKs focusing on rainfall predictions and having biotic factors for predictions were included for the study and were analysed. ITKs collected from other studies are given with reference in superscript and those collected for our study are not having any reference codes.

Region of practice for each ITK and indicators used for each ITK were extracted and listed. Indicators varied widely and they were grouped under three heads-insects, birds and animals and other living beings. Region of practices was grouped under five heads-north, south, east, west and north-east zones.

## Results and Discussion

Rainfall is predicted by using movements, behaviour and visibility of birds, animals and insects by farmers. They are discussed here.

### Insects and their behaviour as indicators of rainfall predictions

In the Table 1, 19 insect indicators are listed which are used to predict rain related phenomenon. Crickets, houseflies, hairy caterpillar, mosquitoes, Thumbi insect, white worm, ants, dragon flies, bugs, termites, spider, grasshopper are some of the insects whose behaviour is observed and considered as indicator to predict rain. These insects have mechanism to sense the atmospheric weather changes, when wind is up, temperature is dropping, solar radiation is decreasing, barometric pressure is dropping it adds up to storm on the way. They use tiny hair like receptors on their cuticle to sense pressure changes. Increasing the temperature to the thermal optima level causes acceleration of the insect metabolism hence their activity increase. In the temperate zone conditions, the average temperature increase leads to intensive and longer total day and night's activity of phytophagous species in forest environment, implied as feeding and mating, as well as time spent on finding proper place for laying eggs.

Timing of movement of bees (morning, evening), their movement (inside/outside) from hives and directions (north/south hill) are used as indicators to predict rainfall in north zone. Numbers of studies have found that honey bees are good at predicting weather. In fact, honey bees seem to be more accurate than the weather channel when it comes to predicting rain. Honeybees not only predict but they can estimate its intensity[4]. A little drizzle may not influence their

foraging patterns, but a heavy storm can keep them home. Honey bees are more defensive during the approach of bad weather. Spike in their defensiveness researchers attributed to meterological factors including temperature, humidity, amount of solar radiation, wind speed and barometric pressure. Regarding movements of honey bees, it is reported that they predict heavy rain so they work hard to collect more food before the heavy rain starts. Bees, because of short lifespan make perfect subjects for studying the effects of climate change. Bees are often referred to as "indicator species" of weather.

Houseflies (I3) become active when atmospheric humidity reaches saturation, which brings rain[5]. Large number of fire-flies (I9) seen at night on the forest trees is a sign that the monsoon will start early[6]. Butter-flies (I10), beetles, dragon-flies (I12) and grasshoppers (I15) expand their geographical range to higher latitudes and altitudes where climatic factors will be less harsh with global warming. Dragon flies moving down (low) in swarms indicate rain within a day or two. Dragon flies move down because of humidity reaches saturation. Dragon-flies are exothermic in nature, the change in temperature influence their behaviour. If grass hoppers (Jhingurs) are in a group of 10-12 then, it is supposed that rain will occur in next 24 h.

When humidity starts to build, millions of normally earth-bound ants sprout wings and take to the skies. Red and black ants (I13) build up their mounds for extra protection or to cover the mounds' holes when there is a bad weather. Increase in humidity lengthens hairs on the body of ants. This triggers ants to carry the eggs to a safer place. This process is observed with

Table 1 —Insects and their behaviours used as indicators for rainfall forecasting in different regions of India

| Code | Insects | Scientific name | Behaviour | Forecast | Zone |
|---|---|---|---|---|---|
| I1 | Bees | *Apis mellifera* | Moving in large numbers towards their hives | Indicate bad weather and rain | North |
| | | | Fly towards northern hill | No rainfall | North |
| | | | Moves towards southern hill | Good rainfall | North |
| I2 | Crickets | *Gryllus campestris* | Calling or chirping throughout the night | Indicate change in weather | North |
| I3 | Houseflies | *Musca domestica* | Become active | Rain | South |
| I4 | Bio *Chakali purugu* | *Scirpophaga incertulas* | Appear in large number | Onset of monsoon | South |
| I5 | Red hairy caterpillar | *Amsacta albistriga* | Becoming restless | Indicator of rain | South |
| I6 | Mosquito | *Culex pipiens* | Increased mosquito bite | Rain | South |
| I7 | Thumbi | *Anax parthenope* | Flies low | Probability of rain | South |
| I8 | White worm Dung fly | *Scathophaga stercoraria* | Crawl over cow dung | Heavy rain | East |
| I9 | Fireflies | *Lampyris noctiluca* | Large number of fireflies seen at night on the forest trees | Monsoon will start early | West |
| I10 | Butterfly | *Papilio machaon* | Appearance of many butterflies | Early rainfall and good season | West |
| I11 | Winged termites | *Coptotermes formosanus* | Appearance | Indicate rains | North , south, east & west |
| I12 | Dragon flies | *Anax parthenope* | Movement of dragon flies low- in swarms | Rain within a day or two | North, south & East |
| I13 | Black ants | *Lasius niger* | Carrying eggs in mouth running in search of safer place | Rain | North , south, east, west & North east |
| I14 | Moth | *Tineola bisselliella* | Appearance in large numbers | Predict drought | West |
| I15 | Grass hopper | *Omocestus viridulus* | Moving in group of 10-12 | Rain will occur in next 24 hours | East and North-east |
| I16 | Spider | *Brachypelma hamorii* | Makes web in vertical to the earth and sky | Rain | North, East |
| I17 | Snail | *Helix pomatia* | Climbs certain trees | No rain | South & east |
| I18 | Tiauhmi bug | *Anax parthenope* | Found in the forest during summer | Rainfall and flooding are about to begin | North-east |
| I19 | Root grub | *Holotrichia reynaudi* | Emergence during second fortnight of April and First fortnight of May | Indicate the onset of monsoon | South |

thousands of ants moving in a stream. Appearance of winged termites (I11) for some days after a dry spell is considered to indicate rains. It is because of the reason that, when atmospheric and soil surface humidity are high then rain is expected, so termites move in large numbers in rows. When the rain is about to begin, the spider (I16) makes its web in opposite direction i.e., vertical to the earth and sky and after rain the direction of web is horizontal to the earth and sky. Spiders generally abandon their web and seek shelter with drop in atmospheric pressure and this observation is utilized by the people for predicting rains.

Insect appearance, flying direction and height, crawling, movement in numbers, carrying eggs etc are behaviour patterns of insects observed by farmers to predict rainfall.

**Birds and their behaviours as indicators of rainfall predictions**

Birds are more sensitive to the effects of weather and climate. Behaviour of Birds is used to predict rainfall. Behaviour of birds like, its unusual activities, nest structure and place, appearance, abundance, flight sound etc are used to predict rainfall. Totally 17 types of birds are listed in Table 2. Swallows, sparrows, stockbill, dinakollelu, parakeets, warbler, bamboo partridge, doves, melong, peacock, partridge, amur falcon, cock, maina, owls etc are some of the bird types whose behaviour is observed by farmers to predict rainfall. Farmers track the movements of birds and observe the changing patterns of nature which have helped them to predict onset of monsoon for centuries. Behaviour of birds like their movement, nesting, bathing, spreading of wings and voice/chirping are observed by farmers to predict rainfall. Ornithologists have long recognised this and related birds movement to weather patterns.

Farmers predict rain based on flock of swallows (B1) moving together with black clouds. Swallows are small birds. Air pressure affects bird. Small birds fly close to the ground when barometric pressure

Table 2 —Birds and their behaviours used as indicators for rainfall forecasting in different regions of India

| Codes | Birds | Scientific names | Behaviour | Forecast | Zone |
|---|---|---|---|---|---|
| B1 | Sparrows | *Passer domesticus* | Flying around the sky with scattered clouds | Indicate rain in the afternoon | North |
| | | | Loud chirping of birds in group and taking dip in water | Imminent rain | North and North east |
| B2 | Domestic hen / cocks | *Gallus gallus* | Searching food during rain | Rain would continue | North |
| | | | Lying on ground by spreading its feathers under sun | Rain | East |
| B3 | Crow | *Corvus brachyrhynchos* | Spreading and moving its wings near river or source of water | Indicate dry spell | North |
| B4 | Owls | *Tyto javanica stertens* | The peculiar squeaking sound of owls | Rain | South |
| B5 | *Rishi pitta bird* | *Pitta brachyura* | Chirping | Occurrence of rain | South |
| B6 | Peacock | *Pavo cristatus* | Making sound early in the morning and late in the evening | Occurrence of rain | South |
| B7 | Partridge (Agili*)* | *Perdix perdix* | Sings after sunrise | Rain in imminent | North-east |
| | | | Sings while raining | Rain will stop for that day | North-east |
| B8 | Doves and Melong | *Treron vernans* | Cries | Heavy rain/flood | North-east |
| B9 | Cuckoo | *Cacomantis flabelliformis* | Sings | Sowing operations starts | South and west |
| B10 | Stock bill (Natagullalu) | *Anastomus oscitans* | Parabola shaped flight | Rain | South |
| B11 | Dinakollelu bird | *Clamator jacobinus* | Movement in atmosphere | Rain | South |
| *B12* | *Parakeets birds* | *Melopsittacus undulatus* | Migration in N-S direction | Presence of moisture and occurrence of rain | South |
| B13 | Swallows (*Hirundo rustica*) | *Hirundo rustica* | Flock of small birds proceeding with black clouds | Rain | North |
| B14 | Acridothers tristis (Maina) | *Acridothers tristis* | Baths in the water pond | Rainfall within 1 or 2 days | North and East |
| B15 | Domesticated chickens (Awu) (*Gallus gallus*) | *Gallus gallus domesticus* | Picking food in rain | Rain continues | North-east |
| B16 | Ground nesting bird | *Mniotilta varia* | Making their nest on higher ground | Heavy rain | North, south, east, west & North east |
| B17 | Tatiharibird (Lapwing) | *Vanellus indicus indicus* | Lays eggs on the higher portion of the lake bunds or on the top of any structure | Heavy rainfall | North, south |

drops. So, low flying small birds are considered as signs of rain. Swallow arrival times were also influenced by temperatures over migration routes[7]. Chirping of Rishi pitta bird *Pitta brachyura* (B5) is an indicator of occurrence of rain. These birds are very sensible to the winds and farmers predict rain if they start chirping. It is also believed that if these birds fly in rows after the occurrences of rain, the possibility of further increase in rain is very high. It is a small bird. These small birds when fly at heights above 0.5 kms, they sense the upper air winds and chirp. Usually, rain bearing clouds occur at heights between 0.5 km and 2.5 kms. Because of the sensible response of these birds to the winds, farmers predict rain. Change in winds at high altitudes (around 0.6 km) leads to sudden movement of Dinakollelu birds *Clamator jacobinus* (B11) in the atmosphere, indicating rains[5]. Domestic hen/cock *Gallus gallus* (B2) lying on ground by spreading its feathers under sun is the indication for rain. Singing of Cuckoo bird (B9) is meant that its time to start sowing seeds in the field. This bird can sense the content of water vapour in air due to motion of sea waves. More water vapour in air would bring coolness and induce these birds to sing. These melodious sounds are often taken as indicators of rain by farmers on any given day during that season. Even singing of Peacock (B6) in the early morning and late evening is also considered as indicator for rain in south region. Similarly, in the north-east region of the country, singing of Partridge (B7) after sunrise is believed to bring imminent rain and if sings while raining then taken as an indicator that rain will stop for that particular day. Clear weather is expected if flocks of birds fly high in the sky.

Many birds nest on the ground (B17). Some of them are game birds, shore birds, waterfowl and some song bird species. Waterfowl birds try to nest close enough to water. This allows female to lead young ones to water to protect from predators. If such birds make their nest not near the bottom of the well/water source then it is believed that there will be heavy rainfall. Contrary to this, if nest is built near the bottom of well/water source, it indicates poor rainfall. Probably these birds decide location of their nest (top or bottom of water source) by observing sky and clouds and then starts weaving their nest. These birds create a nest by doing small depression in the ground lined with grass and feathers. Tatihari bird, the Lapwing (B18) if lays its eggs on higher portion of lake bunds or on the top of any structure it is believed, both in southern and northern part of India that there will be heavy rainfall[8]. One egg indicates rainfall for one month. If two eggs are laid then rainfall will occur for two months and similarly four eggs indicate there will be rainfall during all the four months of the rainy season

Sound of owls (B4), cries of doves and melong (B8), migration of parakeets (B12), bathing by maina (B14), flight of stock bill (B10) and sparrows (B1), spreading of wings by Crow (B3) are other indicators used by farmers to predict rain and its intensity[9-11]. In general birds fly high when sky is clear indicating good weather. Reverse indicates bad weather. Drop in pressure in atmosphere makes the bird uncomfortable to fly high. It takes lot of energy to fly in rainy conditions and so birds avoid doing it. A storm comes in on a low pressure center. This makes it more difficult for birds to fly because of less dense air.

**Animals (& other living beings) and their behaviours as indicators of rainfall predictions**

Behaviour of animals like cows, dogs, goat etc. are considered to predict rain. Totally 10 animals are listed in Table 3. Behaviours like grazing, flocking, sounds of animals are used for the same. Animals are tuned to day length and the seasons. They take cues from nature that helps them in many ways. When clouds are formed at lower level, excess heat is generated due to water vapourisation. This heat cannot be tolerated by sheep and goat. Hence, they form flock which is observed and used by farmers to predict rain. Animals can sense that the days are getting longer or hotter. For instance, when cows (A1) sense bad weather, they become restless and agitated and begin to return home early with raised tail to hit flies. Scientists of Arizona and northern Missouri universities through their scientific study proved that cows lie down when it is cold and stand when it is hot for long hours. Goats (A3) change their usual resting places, show little interest in taking food or water, and bawl and shout the day long. It signals the rain in 2-3 days advance. Increasing moisture causes uneasiness and sweating to goats and changing resting place. Frogs (A8) detect the fall in barometric pressure which allows optimal conditions for the females to lay eggs in fresh pool of water, allowing production of croak sound. Frogs croaking in chorus underneath stones is believed to indicate rain. Also, its believed that frogs due to deficiency of oxygen under stones come out for air and croak. Dogs (A4) barking

continuously and sharply –indicate ensuing rain. This practice is believed both in south and east regions of India. Due to release of heat from water vapour into the atmosphere, cloud formation takes place resulting in restlessness among dogs. They start barking due to this restlessness. When fox (A10) howls irritably at higher place it indicates a forthcoming prolong drier season and when it howls from a low laying location it indicates probability of high flood. Sight of certain snakes (A5) moving down the mountain is considered to indicate good rains. Snakes generally come out of hibernation and proceed to downhill areas in search for prey and mating partners so as to reproduce in early summer season. This is to ensure that the eggs are hatched in time and baby snakes get enough time to fatten their bodies and prepare for cold season when they have to hibernate.

## Common ITKs

ITKs found to be followed in two or more zones of India are presented in Figure 1. Six insect related ITKs ((I11, I12,I13, I15, I16, I17), 5 bird related ITKs (B1, B9, B14, B16, B17) and four ITKs with animals as indicators (A3,A4,A8,A10) are followed in more

Table 3 — Animals and other beings and their behaviours used as indicators for rainfall forecasting in different regions of India

| Codes | Animals and other beings | Behaviour | Forecast | Zone |
|---|---|---|---|---|
| A1 | Cows / yaks | Returning home early with raised tails | Indicate rains | North |
| A2 | Cattle | Jumping | Rain few hours | South |
| | | Look at the sky frequently | Rain | |
| A3 | Goats | Flapping of ears | Rain | South |
| | | Change their usual resting places, show little interest in taking food or water, and bawl and shout the day long | Rain in 2-3 days | North and west |
| A4 | Dogs | Barking continuously and sharply | Rain | South and East |
| A5 | Snakes | Moving down the mountain | Indicate good rains | North |
| A6 | Rats | Come out of their burrows and start to dig the ground | Natural calamity | North |
| A7 | Crab | Comes to the bund | Rain | South |
| A8 | Frogs | Croaking in chorus | Rainfall | North , south, east, west, North east |
| A9 | Humans | Pain in the joints of arthritis patient | Imminent rain | North |
| A10 | Fox | Howls irritably at higher place | Prolong drier | South and North-east |
| | | Howls from a low laying location | Probability of high flood | South and North-east |

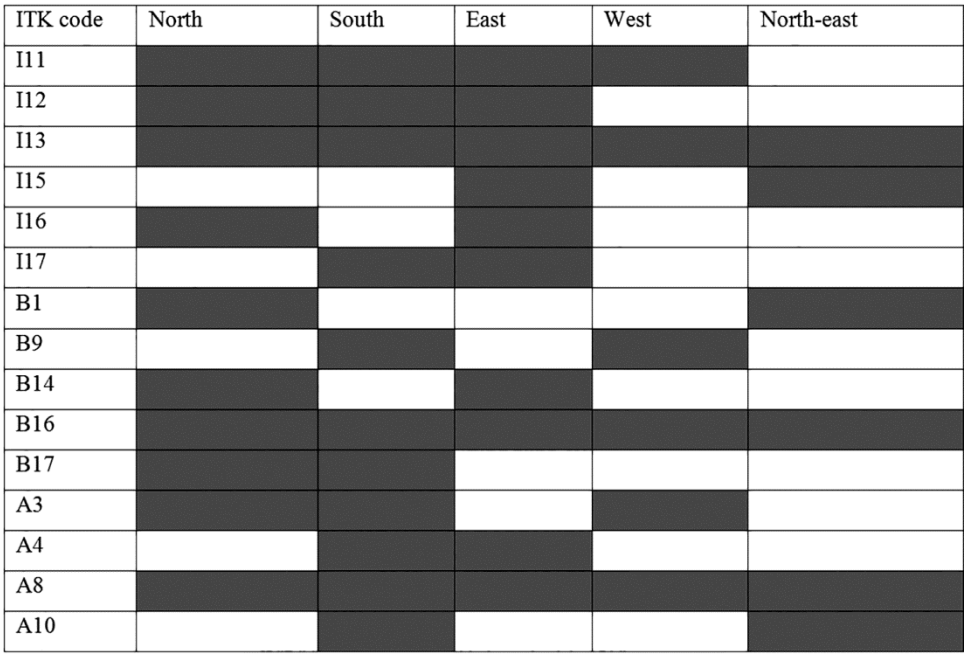


Fig 1 — ITKs followed in more than one zone of India

than one region. Totally 15 ITKs analysed for the study are found in more than one zone. This is interesting considering the vast geography and diversity of the country. Ants, dragon flies, winged termite, spider and snail are used as insect indicators in more than one region. Similarly, sparrows, cuckoos, maina, ground nesting birds among birds and goats, dogs, frogs and fox among animals are used as indicators. These are commonly found across the country. But observations of farmers of different zones to predict rainfall using these as indicators remain same. Observations of farmers are based upon proportionistic spread of these species in the situations where they live and work. These biotic factors are commonly found as well in large numbers throughout the country. So, farmers across the regions would observe them closely to predict rainfall.

These are some grass root innovations for predicting rainfall. Formal science follows experiments and tries to find evidences. Observation of a phenomenon on regular basis and in realistic conditions is equally good. Observation of farmers using different biotic factors should be casted as addition to experiments but not as in opposition to experiments. Much of the observations of farmers and their ability to observe are due to their need to make appropriate decisions about farming. This is crucial for them as their livelihood is governed by their decisions about farming. But there could be confirmation bias. So, validation of these practices through formal research would help to remove confirmation bias and provide scientific explanations to these practices.

## Conflict of Interest

All authors declare that they have no conflicts of interest.

## Authors' Contributions

All the authors have made a substantial contribution to the concept of the article, acquisition, analysis and interpretation of the data for the article.

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