


```

    }
    if (penalty <= average) {
        recordsBelowAverage.add(cr);
    }
    penalty = 0;
}
return recordsBelowAverage;
}

```

```

public ArrayList getAllRecommendations(ArrayList optimumRecords) {
    String recommendations = "";
    ArrayList recommendationList = new ArrayList();
    String recommendation;
    for (Object rec : optimumRecords) {
        for (Object r : (ArrayList) rec) {
            recommendations += ((FeatureRecommendation) r).getRecommendations();
            break;
        }
    }
    StringTokenizer tokenizer = new StringTokenizer(recommendations, ",");
    while (tokenizer.hasMoreTokens()) {
        recommendationList.add(tokenizer.nextToken());
    }
    return recommendationList;
}

```

```

public ArrayList getDistinctRecommendations(ArrayList recommendations) {
    String rec;
    ArrayList newRecs = new ArrayList();
    for (Object r : recommendations) {
        rec = "" + r;
    }
}

```

```
    if (!(newRecs.contains(rec))) {  
        newRecs.add(rec);  
    }  
}  
  
return newRecs;  
}
```

```
public ArrayList getFrequency(ArrayList distinctRecommendations, ArrayList  
recommendations) {  
    int count = 0;  
    ArrayList frequency = new ArrayList();  
    for (Object d : distinctRecommendations) {  
        for (Object r : recommendations) {  
            if (d.toString().equalsIgnoreCase(r.toString())) {  
                count++;  
            }  
        }  
        frequency.add(count);  
        count = 0;  
    }  
    return frequency;  
}
```

```
public ArrayList getDescriptions(ArrayList distinctRecommendationIds) {  
    int count = 0;  
    ArrayList desc = new ArrayList();  
    for (Object obj : distinctRecommendationIds) {  
        String desc = conn.getDescription((String) obj);  
        desc.add(desc);  
    }  
  
    return desc;  
}
```

Appendix B

Consent form

Date:

Title of the research project: **Integration of Indigenous Knowledge, Satellite Imagery, Climate Data and Machine Learning to optimise cropping decisions by small scale farmers. Case of uMgugundlovu district, Kwazulu-Natal South Africa.**

Student name and surname: **John Nyetanyane**

Student number:

Student contact number:

Supervisor(s): Prof M Masinde

Co-supervisor(s): Prof M Tafadzwa

Introduction to the study

The Department of Information Technology at the Central University of Technology (Free State, South Africa) is conducting research aimed at developing a cropping decisions' optimisation model to help local farmers in uMgugundlovu district to increase their crop yields. This is by way of integrating the indigenous knowledge with technology to foresee rains and onset of agricultural seasons to enable farmers to determine perfect times to perform crop cultivation. Further, the indigenous knowledge will be integrated with science and technology to assess the health and development of the crops.

Consent to participate in the research project

I, _____ (participant name), confirm to participation in this research project and that, the person asking my consent to take part in this research has introduced the study to me and highlighted its purpose.

I have read (or had explained to me) and understood the study as explained in the research study information and consent form. I have had an opportunity to ask questions and am prepared to participate in the study. I understand that my participation is voluntary and that I am free to withdraw at any time without penalty. I am aware that the findings of this study will be processed into a research report, journal publications, and/or conference proceedings. I am fluent in English and understand these documents or I have had the information explained to me in a language I understand well.

Full Name of Participant:

Signature of Participant: _____ Date:

Appendix 3

Collection of the Indigenous Knowledge Indicators in different domains

Indicators Nature	Warm Rainy Season Indicators (August to December)
Meteorological	Cold temperatures during warm dry season Hot temperatures during cold dry season Strong winds in August good rains at the beginning of the season Distributed clouds, clear sky, but heavy clouds appearing on the eastern side of the sky Low cloud after rains Strong haze(mist) in September Red sky in the west towards sunset Hot and damp conditions after rains Cold winds after rains bright sun but with no much heat output bright sun and very hot conditions in September Very strong North to west wind direction Presence of dew(water vapour) in the morning Delay of rains for a long time (about 2 weeks to a month) High temperatures before or after rains Heavy fall of rain before actual rains
Astronomical	Visible phases of the moon Dark phases of the moon Appearance of dark or small few clouds on the sky Pattern of stars forming hoe striking the ground Pattern of stars forming a roofing mat Dark clouds underneath and white clouds on top Disposition or Slanted position of the moon in September Presence of mist during the dry season When the sky is very clear When it is very sunny and hot Appearance of rain clouds at daytime and disappearance at night A very small circle around the sun and no circle around the moon A pattern of 7 stars appearing in the East Sky is full of stars at night Appearance of circle or circles around the moon and the sun Few stars in the sky Shading of the sun The moon moves from East to West A pattern of stars remains at the central position
Environmental(Birds)	Sighting of inkonjane birds at the beginning of rainy season Movement of bees and birds from east to west and north to south Appearance of many birds in groups Sighting of an owl at daytime at the beginning of the rainy season Birds named Speros singing When the bird named ijuba hang nests low the tree When the bird named ijuba hang nests very high the tree Sighting of Large number of white and black birds named (Mashohori) at the beginning of the season A black-brown bird named umgugwane start singing during the dawn When the red chested bird start singing in the afternoon at the beginning of the rainy season
Environmental(Insects)	Appearance of dragon flies, white butterflies and other insects at the beginning of rainy season Hasty spiders struggling to get indoors or into hiding places Invading of locusts Ants moving in a straight line

	Sighting of black and brown ants collecting food in large numbers in the house
	Ant named inkuba singing in large numbers
	Appearance of red ants named umkothane
	Appearance of termites (flying insects)during the rainy season
	Appearance of army worms on trees towards the beginning of the rainy season
	Occurrence of large number of grass-green grasshoppers during the rainy season
	Presence of too much honey in the hives indicates
	Appearance of insects and birds in less number
	Disappearance of certain birds/insect species (e.g. weaver birds)
	Millipede, ilulwane(bat) and crickets making noise at night
	Appearance of certain ants such as louse(umkhuphe), aphids(i-afidi)
	Invasion of locusts
Environmental(Animals)	Frogs making lots of sound
	Frogs fail to make noise
	Mating of local animals
	Appearance of white frogs in the grass
Environmental(Trees)	When the umhlaba tree starts to flower and generate new leaves at the beginning of warm rainy season
	Germinating of plants
	When the peach tree gives a lot of sap during the dry season
	The shooting of sausage tree
	Significant flowering and good fruit bearing of umvumvu tree
	Unusual shedding of the flowers of apricot tree
	Flowering of the plant named umphafa before onset of rains
	When the leaves of umnqumo plant turns yellow at the beginning of the rainy season
	Good harvest of certain trees

Appendix D

Pool of questions prepared for focus group discussion

1. How does the observation of IK indicators impact your certainty of the anticipated season behaviour?
2. How do you know that it is time to plant?
3. How do you estimate crops to cultivate for the predicted season behaviour?
4. How do you estimate the arrival of a high crop insect population concerning the anticipated season behaviour?
5. What crops do you cultivate during warm rainy and cold rainy seasons?
6. What crop, weather and other external properties are you observing to determine the health of a crop
7. How do you know that it is time to apply fertilisers?
8. How will the knowledge of anticipated rains and temperature assist in evaluating the health of a crop?
9. How will the knowledge of rain predictions assist in applying pesticides and fertilisers to your crops? For instance, if I know that rain is not coming soon, can I continue to apply fertilisers and pesticides to my crops?
10. What organic fertilisers do you apply to your crops and soil?
11. What symptoms observable on a tomato crop or any other crop that needs fertilisers?
12. What are the symptoms of crops suffering from over-fertilisation, heat stress or water imbalance (overwatering or underwatering)?
13. How can one help the small sorghum crop or any other crop that is suffering from over-fertilisation or heat stress?
14. How do you know it is time to apply pesticides?
15. What properties do you use to assess the health of the soil?
16. What organic methods do you use to lessen the use of chemicals in treating crop intruders (weeds, insects and diseases) and improving soil fertility?
17. What kind of crops can be cultivated on clay/sandy/loam soil when there is an expectation of below/normal/above normal rains throughout the season?
18. How will you tell if the crop in question is suffering from bacterial or fungi or virus disease?
 - a. How will you help that particular crop?

19. What kind of crops that can be cultivated if normal rains are expected to start late during the rainy season (for instance late December)?
20. How can I help the development of my small crops given that there is an expectation of above or below-normal rains coming soon
21. How can I help the development of my small crops that start to show signs of leaf wilting given that there is an expectation of no rains and higher temperatures in the coming weeks?
22. How can I help the development of my small crops that are cultivated on sandy soil given that there is an expectation of no rains and higher temperatures in the coming weeks?
23. What can be done to help the small maize crop that is showing signs of leaf wilting given that the crop is exposed to hot temperatures, low wind speed and high humidity?
24. What can be done to help the 4-weeks-old pumpkin crop that is showing signs of leaf wilting, leaf swelling and leaf discolouration?
25. What can be done to improve the growth of potato crops and other crops that are suffering from stunted growth (slow growth)?
26. What can be done to improve the growth of soybeans, or any other crop given that they are exposed to hot temperatures with low humidity and low wind speed? Further, the crop is cultivated on loam soil that is red and compacted.
27. How can you tell if the given crop problems are attributed to disease attacks rather than external factors such as heat?