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Temperature Guidance Making to Utilize the Rice Production

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ABSTRACT

Rice is Sri Lanka's most popular staple food, and paddy cultivation is one of the country's primary industries, with a substantial impact concentrated in a few large regions. Paddy farming in sri lanka faces several environmental, economic, and human issues. One of the driving factors that directly impact paddy production is temperature. Every stage of the rice plant will be affected by temperature between seeding and harvesting. Rice plants will be positively affected between specified temperature ranges; otherwise, the temperature would have a negative impact on paddy harvest. Using multiple linear regression as a technique, temperature guidance was created using numerical weather prediction (nwp) data and the r programming language to provide temperature forecasts. Numerical weather prediction (nwp) is a method of forecasting the weather based on initial weather conditions by using mathematical models of the atmosphere and oceans. The numerical integration of the governing equations with an initial condition provided by meteorological measurements is used to calculate the time evolution of the atmospheric circulation. With the help of identifying of the relationship between temperature and rice harvest using some acceptable methods, it will make some sense in future research when creating temperature guidance.

Keywords-- Temperature, Weather Forecasting, Paddy Harvest, Guidance

I. INTRODUCTION

Climate change has had a significant impact on human life, the environment, the economy, and society. The state of the atmosphere around us at any given time is referred to as weather also. A combination of current meteorological components can be defined as the weather. The weather statistics over a longer period of time are referred to as climate. It can be thought of as the average weather for a specific region that varies slowly over months or longer periods of time.

The near future Because of increased greenhouse gas emissions from human activities, the climate is likely to be significantly different than it is now. Climate changes are required to assess the effects of these changes on human activities and the environment. We call it weather forecasting because if we could predict these scenarios, it would have a huge impact on the human life cycle. Weather forecasting can be defined as the attempt to predict future weather conditions which are made by collecting qualitative data about the current state of the atmosphere. There is various kind of weather forecasting. Persistence forecasting, Climatology forecasting, looking at the sky, Use of a barometer, Use of Forecasting Models, Analogue Forecasting, Ensemble Forecasting, etc.

Based on the basic laws of physics, with the use of differential equations alongside with computer programs that simulate weather patterns over time Climate models can produce. The history of climate modeling begins with conceptual models, followed in the 19th century by mathematical models of energy balance, radiative transfer, and simple analog models. After that, the principal climate science tools have been computer simulation models of the general global circulation.

These mathematical equation simulations are described how variables such as temperature, pressure, and wind change over time. These simulations were run by huge supercomputers run. Observations are also helpful to develop the models in verifying the period. These observations were taken using weather balloons, satellites, commercial aircraft, and buoys. (Troccoli, 2010) (Iseh & Woma, 2013)

Climate models can be divided into two categories based on their geographic coverage. The global circulation model (GCM) and the regional climate model are the two models (RCM). So, when we move from the global climate model to the regional climate model, Climate downscaling is used. (Fan et al., 2013) Downscaling is the general name of the procedure to take information known at a large scale to make predictions at local scales. There are two main approaches to downscaling. They are dynamic and statistical downscaling. Dynamical downscaling is the dynamical extrapolation of the effects of large-scale climate phenomena to regional or local scales of interest using high-resolution regional simulations. For Statistical downscaling, a statistical relationship is developed

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between the historic observed climate data and the output of the climate model for the same historical period. (Giorgi, 2006)

Globally, rice is an important cereal crop and the primary source of staple foods for over half of the world's population, especially people living in Asia and Africa. (Fahad et al., 2018) Sri Lanka's main occupation is agriculture, and its economy depends on its agriculture. (Lanka, 2009) Sri Lanka is a small, tropical island country south of the Indian mainland with approximately 21 million. Agriculture of Sri Lanka is one of the major incomes for the people, and almost all of the locally consumed rice, vegetables, and potatoes are cultivated in Sri Lanka. Rice is the staple food in Sri Lanka, and it is cultivated by farmers on a small scale in rural regions, principally in the northern and eastern plains. Rice is produced in two cropping seasons, Maha and Yala, and the production is localized as dry zone and wet zone based on the agro-climatic parameters of the producing regions. The dry zone contributes to 60% of the annual rice production, and the area receives most of its rain from North-East monsoons. (Punyawardena, 2009) There are several factors that can affect rice production, environmental factors, economic factors, human capital and population, government policies, technology, etc. The crops we grow for food require specific climatic conditions to perform better in economic yield. Crops may benefit or suffer as a result of the changing climate. Climate change has a significant impact on agriculture.

This research only considered about temperature. Measure of the average kinetic energy of the molecules of a substance can be defined as temperature. A thermometer measures the quantity. The meteorology department of Sri Lanka measures the temperature in several ways for a day.(Subash & Sikka, 2014) (Amin et al., 2015). And we are targeting making a temperature model and making some predictions about future temperature varying. Then using that prediction, we try to identify how it can be affected rice production. In this research, the major target is making suitable temperature guidance for selected districts separately. Then try to identify the effect of temperature on rice production in Sri Lanka using historical data. (Ratnasiri et al., 2019)

The climate model is going to make using multiple linear regression (MLR) for that it needed Numerical weather prediction data (NWP), which meteorological departments supply from their servers.

In 1922 Lewis F. Richardson proposed about ‘‘Weather Prediction by Numerical Process’’ to predict change of the atmospheric circulation by numerical integration of governing equations for the atmospheric circulation.(Kimura, 2002)

The atmospheric circulation is very sensitive to the initial condition because of the non-linear characteristics of the governing equations. Small errors in the initial state grow exponentially and the simulated atmospheric state deviates from the actual atmospheric field. Therefore, providing a good initial state is a key factor of the numerical prediction.

The basic principle of the present NWP is exactly the same with that proposed by Richardson. Time evolution of the atmospheric circulation is calculated numerically by integrating the governing equations with an initial condition which is provided by meteorological observations. Nowadays, most NWPs are performed based on the global model.(Bauer et al., 2015)

But There are two main reasons for unsuccessful this scenario. First one is the bad initial condition, because there was little upper-air sounding at that time. The other is a fact that hydrodynamic characteristics of the atmospheric circulation were not well recognizing which makes the correct time integration extremely difficult.

The numerical model of the climate is almost the same with that used in the short-range weather forecast and boundary conditions at the surface of the Earth play a crucial role in the climate model. An atmospheric model is a computer A program that generates meteorological data for future times at specified locations and altitudes. A set of equations known as the primitive equations are used to predict the future state of the atmosphere in any modern model. Furthermore, the model's partial differential equations must be supplemented with parameterizations for solar radiation, moist processes (clouds and precipitation), heat exchange, soil, vegetation, surface water, and terrain effects.

However here we are using NWP data which was divided in to 15 different predictors. Using the multiple linear regression method, we are attempting to identify the most appropriate predictor combination for selected districts. They are all thought to be predictors.

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1. Tsfc: Temperature on the surface (C)
2. Rain: Precipitation amount during previous 3 hours (mm)
3. H700: Relative Humidity at 700hPa (%)
4. Usfc: Wind u-component (West-East) on the surface (m/s)
5. T850: Temperature at 850hPa (C)
6. W700: Vertical wind at 700hPa (Pa/s)
7. Vsfc: Wind v-component (South-North) on the surface (m/s)
8. H850: Relative Humidity at 850hPa (%)
9. Z500: Geo-potential height at 500hPa (m)
10. Fsfc: Wind speed on the surface (m/s)
11. W850: Vertical wind at 850hPa (Pa/s)
12. H500: Relative Humidity at 500hPa (%)
13. Hsfc: Relative Humidity on the surface (%)
14. T700: Temperature at 700hPa (C)
15. W500: Vertical wind at 500hPa (Pa/s)

This temperature model can be created using various computer languages, but on the statistical side, R is the mostacceptable and highest rated computer language and is much more user-friendly. As a result, the R programming language is used to create the temperature model. (Harris, 2018)

Then there must be a way to apply this developed model to the temperature effect in rice production that was chosen. The developed temperature model can be used to utilize rice production after identifying the temperature's relationship to rice production in a specific area

II. STUDY AREA

Colombo District is located in the south west of Sri Lanka and has an area of 699 square kilometres. Its geographical coordinates are 6°51'59" North 80°0'60" East and elevation above sea level is 6 m.

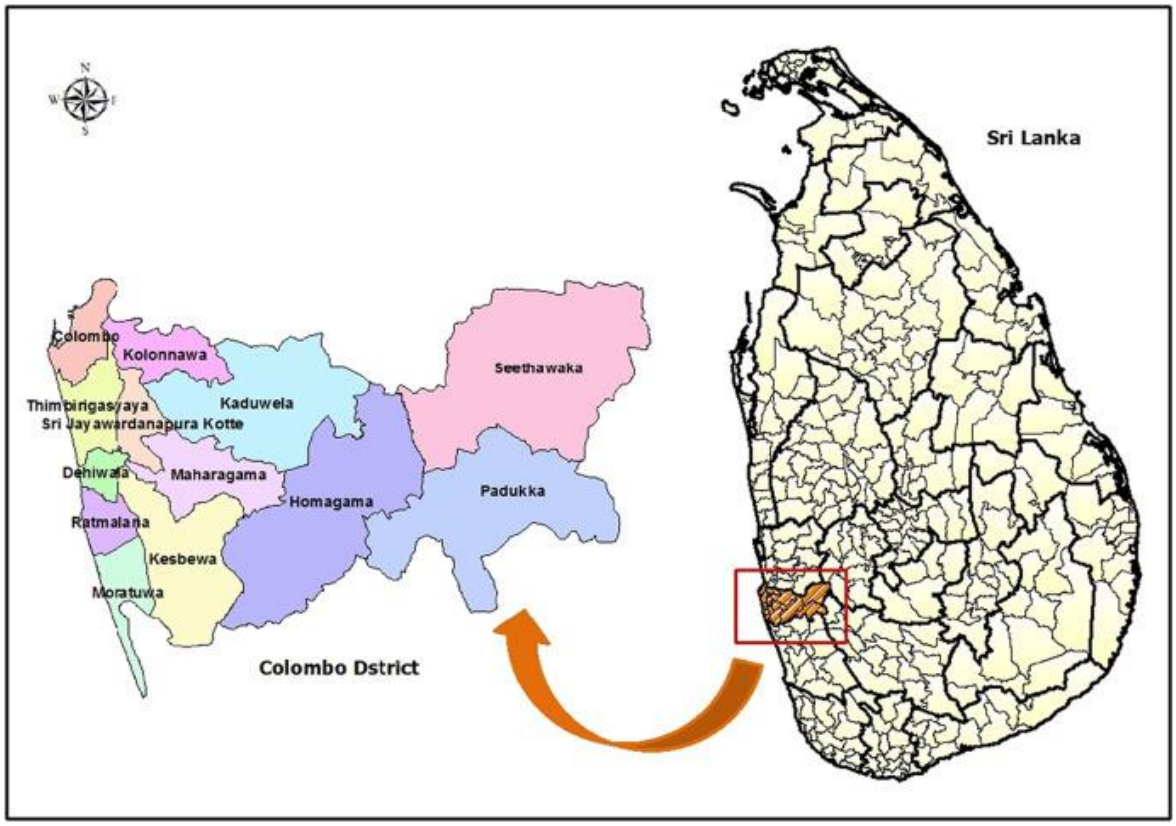

Figure 1: Selected districts in Sri Lanka Map
(https://www.sciencedirect.com/science/article/pii/S2666049022000615)

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III. DATA

NWP data for Colombo district was selected to make temperature guidance for Colombo.

Data was given by meteorology department of Sri Lanka and they called as NWP data. These data are taken by using their servers and there is a simple procedure to convert this data file. It can be described by using three steps.

I. Collect NWP Data

00UTC and 12UTC temperature reported by SYNOP (surface synoptic observations) is a numerical code used for reporting weather observations made by human-crewed and automated weather stations.

II. Convert NWP Data

1. Select the target point.
2. Select period (develop Mar-Apr. 2012, verification May-Jun. 2012)
3. Select time [time of observation is 12UTC (00UTC FT=12hour)]

iii. Divide them as development and verification data. (Development and verification data have only one difference between each other, which is the period.)

So here data was selected from 2012 March - Apail and 2012 May - June in Colombo district.

IV. METHODOLOGY

Multiple Linear Regression

Multiple linear regression is use to make temperature model and here situations where the response variable is linearly dependent on more than one explanatory variable.(Lee et al., 2015) Suppose we've four explanatory $X1$, X 2, $X3$, and $X4$, variables and one response variable Y, the observed process would be

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon = \beta_0 + \sum_{j=1}^{4} \beta_j X_j + \varepsilon$$

Which we can model by,

$$\hat{Y} = b_0 + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 = b_0 + \sum_{j=1}^{4} b_j X_j$$

Where $b0$ and ε are the slope and error terms and the $bj\ '\ s$, $\in 1$. .They are the estimated coefficients of the $Xj\ '\ s$, $j \in 1$. The equation displayed above is the multiple linear regression equation when we have 4 explanatory variables. The generalized multiple linear regression is given by;

$$\hat{\mathrm{Y}} = b_0 + b_1 X_1 + b_2 X_2 + \cdots + b_n X_n = b_0 + \sum_{j=1}^{n} b_j X_j$$

Where Yi is the actual or observed value of the response value and $\hat{\mathrm{Y}}i$ is the fitted value in the instance (Where N is the number of data points in the data set). We fit a linear relationship between independent and dependent variables in multiple linear regression. However, the slope and coefficients cannot interpret as those of the simple linear model of $\hat{\mathrm{Y}} = b0 + b1X$ with one intercept $b0$ and one slopes $b1$.(Prabhakar et al., 2019)

Root Mean Square Error (RMSE) and Mean Error (ME)

The root mean square error has been used as a standard statistical metric to measure model performance in meteorology, air quality, and climate research studies. . The mean error or mean absolute error (MAE) is another useful measure widely used in model evaluations. While they need both been used to assess model performance for several years, there's no consensus on the foremost appropriate metric for model errors. (Chai & Draxler, 2014)(Savage et al., 2013)

To simplify, we assume that we have already got n samples of model errors calculated as the uncertainties brought in by observation errors or the method used to compare model and observations does not consider here.(Ng & Awang, 2018) We also assume the error sample set is unbiased. The RMSE and therefore the MAE is calculated for the data set as,

$$\mathrm{ME} = \frac{1}{n}\sum_{i=1}^{n} |e_i|$$

$$\mathrm{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} e_i^2}$$

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We present that the RMSE is not ambiguous in its meaning, and it is more appropriate to use than the MAE when model errors follow a normal distribution.(McKeen et al., 2005)

Correlation Coefficient

Let "a" and "b" be two zero-mean real-valued random variables. The Pearson correlation coefficient (PCC) can define as;

$$\rho(a,b) = \frac{E(ab)}{\sigma_a \sigma_b}$$

E (ab) is the cross-correlation between a and b, and σ_a^2 = E$a^2$and σ_b^2 = E$b^2$are the variances of the signals a and b, respectively. In the rest, it will be more convenient to work with the squared Pearson correlation coefficient

$$\rho^2(a,b) = \frac{E^2(ab)}{\sigma_a^2 \sigma_b^2}$$

One of the most important properties of the SPCC is that

$$0 \leq \rho^2(a,b) \leq 1$$

(Mukaka, 2012)

The SPCC indicates the strength of the linear relationship between the 2 random variables a and b. If ρ^2 (a, b) = 0, then a and b are said to be uncorrelated. The closer the value of ρ^2 (a, b) is to 1, the stronger the correlation between the 2 variables. If the 2 variables are independent, then ρ2 (a, b) = 0. But the converse isn't true because the SPCC detects only linear dependencies between the 2 variables a and b. For a non-linear dependency, the SPCC could also be equal to zero. However, in the special case when a and b are jointly normal, "independent" is like "uncorrelated." (*Corelation Cof.Pdf*, n.d.) (Onwuegbuzie & Daniel, 1999)

Linear Regression Analysis

Regression analysis is the art and science of fitting straight lines to data patterns. In a linear regression model, the dependent variable is predict from k other independent using a linear equation.(Fraley et al., 2011)
The coefficient of correlation between X and Y is the average product of their standardized values,

$$r_{XY} = \frac{X_1^* Y_1^* + X_2^* Y_2^* + \cdots + X_n^* Y_n^*}{n}$$

The correlation coefficient is a number that lies somewhere between -1 and +1, where -1 indicates an ideal negative linear relationship, +1 indicates an ideal positive linear relationship, and 0 indicates no linear relationship. In Excel, correlations are often calculate using the CORREL function.(Onwuegbuzie & Daniel, 1999)

V. RESULT AND DISCUSSION

Temperature Guidance Making

Colombo district NWP data from 2012 is being used to develop methodology for guidance making in R. To begin, the code was created using March-April 2012 data to provide temperature guidance. Previously, the accuracy of the prediction was tested using NWP Tsfc values and exact observations. Predictors can choose between two methods: objectively selecting with a step function or manually selecting without a step function (selecting predictors subjectively). So we proceed to that step and attempt to find the best guidance equations. Another six combinations were found subjectively using correlation plots between Observations and Predictors and by repeatedly trying new different combinations. Also, the developing and verifying periods were checked only once, and four different guidelines were chosen. These results cannot predict which equation is the most appropriate, but by using error values, we can select the best equation sets that can reduce error values as much as possible.

R^2 is probably the foremost popular measure of how well a regression model fits the info. R2 could also be defined either as a ratio or a percentage. Since we use the ratio form, its values range from zero to one. A value of R2 near zero indicates no linear relationship, while a worth near one indicates an ideal linear fit. Although popular, R2 shouldn't be used indiscriminately or interpreted without scatter plot support.(Das, 2018)

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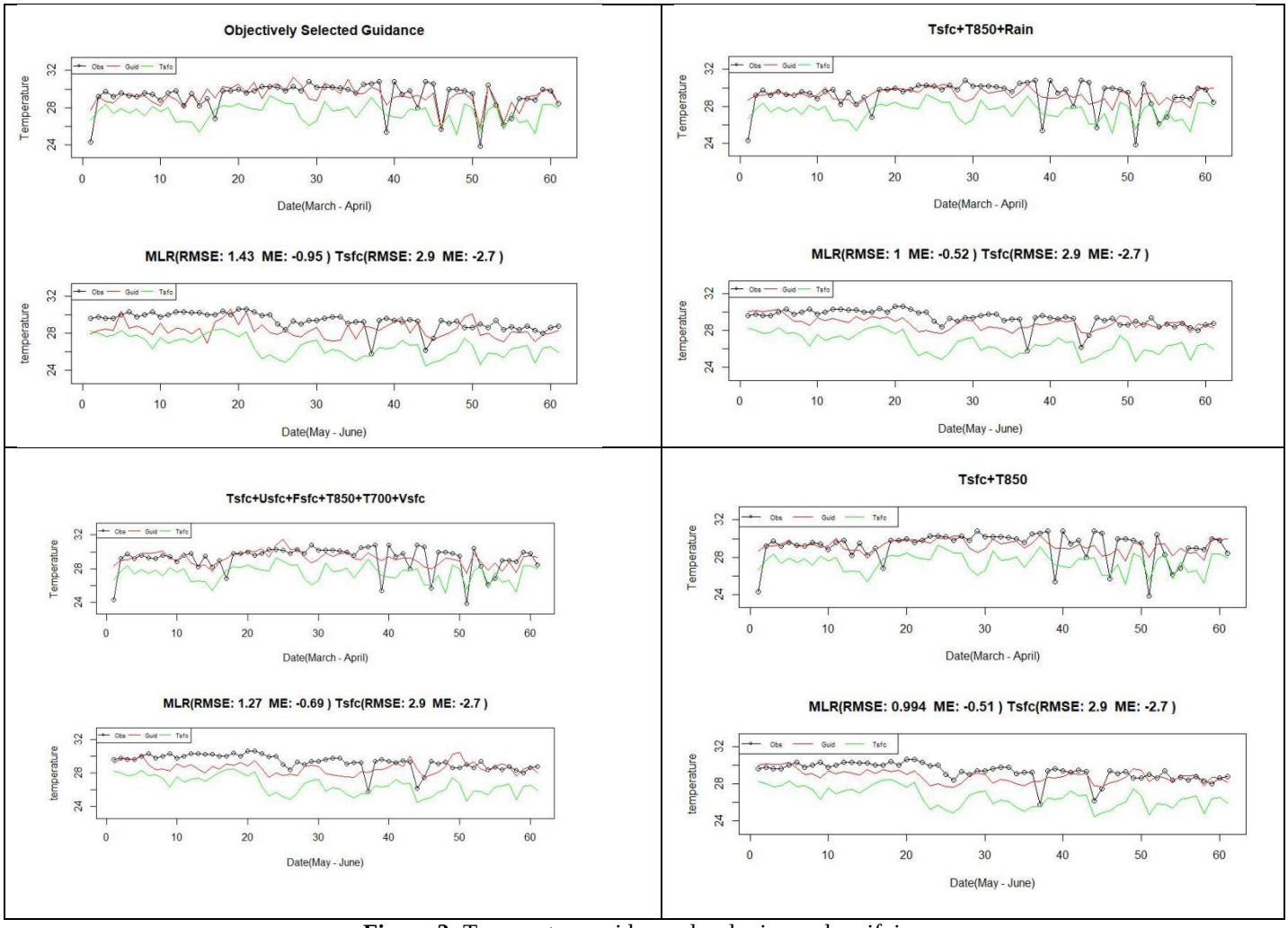

Figure 2: Temperature guidance developing and verifying

The objectively selected combination has a much higher root mean square error, and means error values. A Tsfc + T850 combination includes the smallest mean error and also root mean square error.

The most notable fact is that all of these subjectively sleeted predictor combinations outperform objectively selected combinations, and all of these combinations outperform basic NWP predictors. This temperature guidance has been completed for the Colombo district. However, the methodology used for the Colombo district and all codes are applicable to any area in Sri Lanka or globally, and can be used to generate temperature guidance. However, NWP data is required.

VI. CONCLUSION

Considering different and most possible predictor combinations for the Colombo district, two combinations were selected.

The most suitable temperature guidance was selected for Colombo district.
They are;

I. Tsfc+T850+ Rain
II. Tsfc+T850

Here The rain factor can be so unpredictable and it could be a driving variable that can suddenly affect temperature changes. Because of that, including the "Rain" factor can cause change accurate of guidance both good and bad sides.Because of that Tsfc+T850 combination was identified as the final solution for temperature guidance.

Tsfc, T850 are the predictor combination, and the selected guidance was =
19.0218202 + 0.6064541(Tsfc) - 0.3515139(T850)

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RECOMMENDATIONS

Temperature and rice production were discovered to be related in Sri Lanka. So, if temperature guidance can be made separately for selected areas in Sri Lanka, it could be much more effective in identifying the solution that can be made to increase rice production. Several methods for forecasting temperature are already in use in the meteorology department, but we all know that these are only predictions. As a result, using another method to forecast will aid in making accurate predictions.So, when making predictions based on temperature guidance, it may be more practical to use at least twelve guidance for each district over a twelve-month period. So, using the same method, it is much easier. Furthermore, technology is changing at a rapid pace, so there must be many things to develop methods for. As a result, further research could lead to much better results.

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