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Research Article

TEMPORAL AND SPATİAL ANALYSİS OF RİSKY SİTES FOR LİVESTOCK PRODUCTİON İN SOMALİA

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ABSTRACT

Temperature stress usually occurs in hot-humid areas, especially in the hot summer months. The increase in the relative humidity with the environmental temperature outside the normal limits adversely affects the well-being and productivity of farm animals. The temperature-humidity index (THI) is employed as a generic criterion in determining temperature stress in this research. This research used GIS and THI techniques to determine suitable locations in Somalia for creating cattle and agricultural sheep production following regulatory and technical standards. Several geostatistical techniques, including deterministic methods (Inverse Distance Weight (IDW) and Radial Based Methods (RBF)) and stochastic (Ordinary kriging (OK) and Co-kriging) (CoK), were used to produce THI maps for Somalia in the GIS environment. Twelve monthly THI maps were obtained, and the geostatistical approach with the minor inaccuracy for each month was chosen, as well as the relevant prospective livestock regions. According to the findings, THI values exceed the danger limit (THI = 79) in March, April, May, June, July, August, and September. Therefore, to prevent the adverse effects of temperature stress, some strategies should be followed between March and September in areas with high THI values, such as the construction of shading areas and animals' feeding times during cooler periods.

Keywords: Temperature-Humidity Index, GIS, Relative humidity, Temperature,

İntroduction

As a result of rapid population growth and significant developments in industrialization around the world, water, air, and soil quality have decreased rapidly, and it has become more challenging to meet the nutritional requirements of humankind. In this context, the livestock sector has become an important sector that needs to be developed to meet the dietary needs of the growing population (Unal et al., 2013).

Livestock sector: It is an indispensable sector due to the production of essential products such as meat and milk, which are necessary for a balanced and adequate diet, creating a work area and evaluating plants and vegetable residues that cannot be consumed as human food. Therefore, it is essential to human life and the country's economy. Among the agricultural sectors, livestock is the most likely to create added value.

If the maintenance of livestock breeding is carried out well, it is possible to increase the yield. However, it is impossible to reach the desired yield in all conditions through only maintenance and feeding. Therefore, in addition to these, it is necessary to consider its environmental conditions. Animals' lives are intertwined with the physical and psychological factors around them. Environmental conditions are an important part of physical factors. Extreme environmental conditions can have major effects on the productivity and health of animals. These effects can have different results in different animal species and different breeds within the same species. The effects of environmental conditions vary depending on factors such as the age, sex, and level of productivity of animals. Animals that adapt, breed, and yield to the climatic conditions present in a region may experience some adaptation problems in the event of changes in these conditions, and even deaths may occur in young animals (Kaliber, 2012).

Temperature, humidity, air movement, radiation, and wind are important environmental factors for cattle and sheep, economically cultivated farm animals. The first thing that comes to mind from the climatic factors that affect farm animals is the environmental temperature. In general, stress begins when the ambient temperature rises above 25 °C. In cases of temperature stress, animals show several physiological responses to eliminate the negative effects of environmental temperature. The first obvious reaction of animals under temperature stress is decreased feed consumption (Ataman and Çoyan 1997). Decreases in feed consumption due to temperature stress also result in decreases in milk yield (Harris, 1992).

The optimal environmental conditions for dairy cattle can be achieved between 13–18°C temperature and 60–70% relative humidity values. In general, temperature stress in dairy cattle occurs in conditions of 26–32°C environmental temperature and 50–90% relative humidity (Fidler and VanDevender 2015). Studies determined that there was a 10–40% reduction in milk yield of cows at an environmental temperature of 21–26°C (Brody et al. 1954).

Although the optimal environmental conditions for sheep and goats are temperature values between 20.10 and 26.10 °C, milk causes negative effects on thermal and energy balance, mineral metabolism, immune function, breast health, and milk production when it rises to 28.50 to 33.80 °C (Sevi et al., 2001).

Various indexes can be used to estimate the degree of heat stress in farm animals. The commonly used method for determining the effect of heat stress on animals is the temperature-humidity index (THI) value. If the THI values developed for cattle exceed 72, it is considered the beginning of heat stress. Values above this led to a decrease in feed consumption in cattle. If the THI value exceeds 77, a rapid decrease in feed consumption occurs. For sheep and goats, when the THI value exceeds 23.30, it negatively affects animal health, welfare, and productivity.

Many countries can easily detect environmental and spatial problems in livestock enterprises using Geographic Information Systems (GIS). In addition, these systems are used for different purposes, such as control of diseased animals, determination of animal numbers by species, and monitoring of animal movements (Flower and Senkul 2006).

In this study, GIS and THI methods were used to determine the most suitable areas for establishing cattle and sheep farming enterprises in line with legal and technical principles in Somalia. For this purpose, THI maps were made using different geostatistical methods from deterministic methods (Inverse Distance Weight (IDW) and Radial Based Methods (RBF) and from stochastic methods (Ordinary kriging (OK) and Co-kriging (CoK) in the GIS environment for Somalia. Twelve monthly THI maps were obtained, the geostatistical method that gave the least error for each month was selected, and the appropriate areas for livestock were determined.

MATERIAL AND METHOD

Determination of the research area

The livestock population in Somalia consists of more than 28 million sheep and goats, close to 5 million cattle, and 6.29 million camels (Table 1), FAO (1988). Cattle breeding is most likely in the Juba Valley, while sheep and goat farming is most likely in the Northeast part of Somalia (Table 2). In Somalia, sheep, goats, and cattle exports contribute to more than half of agricultural exports and, together with the livestock sector, account for 80 per cent of total exports. It was deemed appropriate to conduct the research in Somalia to develop the livestock sector, a primary source of income in the African economy.

Table 1. Number and proportion of animals in Africa and Somalia (million heads) (%)

Animal type	Total number of animals in Africa	Total number of animals in Somalia	Rate	range
Cow	202.59	4.61	2.6	8
Sheep	212.67	11.83	6.3	6
Goat	180.30	16.16	9.6	4
Horse	4.79	0.001	0	27
Donkey	13.58	0.02	0.2	23
Mule	1.37	0.02	1.5	5
Camel	14.44	6.29	42.9	1
Poultry Animals	1115.00	3.00	0.3	39
Total	607.776	37.44	5.9	

Table 2. Number of animals of different regions in Somalia (million heads)

Region	Camel	Cow	Sheep	Goat	Total
Somaliland	1.30	0.31	5.83	4.79	12.24
Puntland	1.35	0.43	3.44	7.09	12.32
Galmudug	1.00	0.46	1.09	0.37	2.93
South Somalia	1.21	1.34	0.70	1.86	5.12
Jubbaland	1.41	2.06	0.74	2.04	6.26
Total	6.29	4.61	11.83	16.16	38.90

Location and topographic structure of the research area

Somalia is located between 11° 59' north and 1° 39' southern latitudes and 41°-51° 24' eastern longitudes in northeast Africa, with an area of approximately 640,000 km2. Somalia's territory consists mostly of highlands and plains (Figure 1).

The northern region of Somalia is mountainous, with an average height ranging from 900–2000 m. The highest point in the country, Mount Mijirtein, is about 2515 m high. The plateau formed by the Shebelle River, located to the west and south of this mountain, averages around 685 m. There is farmland between the Shebelle and Juba rivers. The terrain is getting lower and lower towards the Kenyan border. Both the country's rivers are born in Ethiopia and are used to meet irrigation needs.

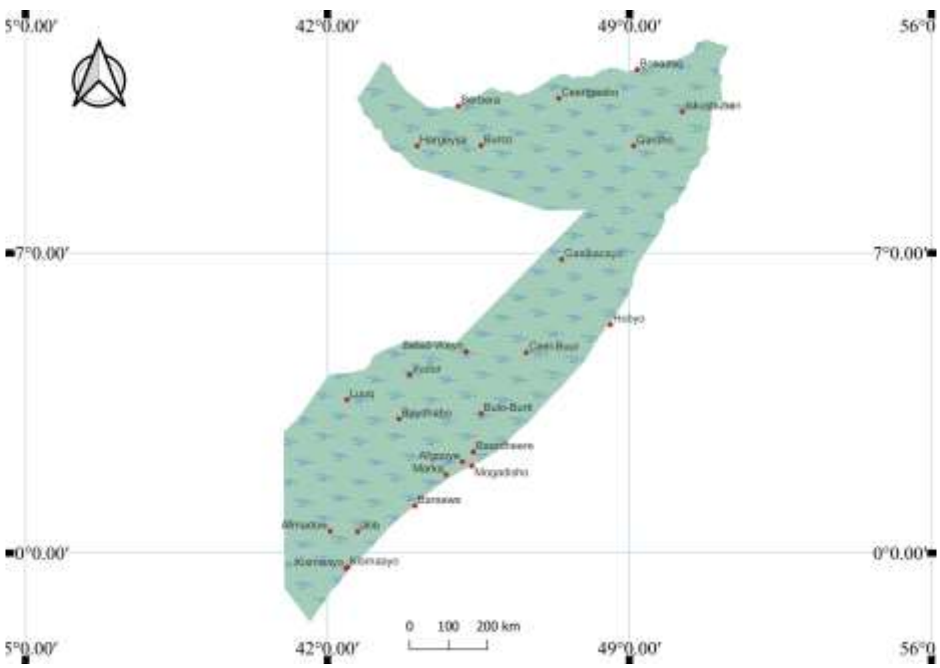

Figure 1. Location of the research area

Climate characteristics of the research area

An arid and semi-arid climate often dominates Somalia. The strongest winds occur between June and August, while the lightest winds usually occur in southern Somalia as they pass into the ITCZ Equator from April to May. In March, the highest average monthly temperatures occurred in the southern cities of Baardheere, Luuq, and Afmadow (31-33°C) and Berbera (36-38 °C) in the north. The relative humidity is higher in areas closer to the southern, central coastline, Juba, and Shebelle rivers and is between 70-80% on average. In the northern regions, it has relatively low relative humidity (65-70%) (Table.3). The coastal areas of the Juba and Shabelle rivers have an annual rainfall of 700–800 mm, while the average annual precipitation in the inland regions of the north-east coast (Lasanod, Qardho, and Scuscuban) is 200–300 mm. (SWALm 2007).

Meteorological data consisting of temperature and relative humidity were obtained from the Somalia Water and Land Information (FAO SWALIM) climate Database (Table.3). The stations used in the analysis are shown in Figure 1.

Table 3. Climate characteristics of the research area

Station	Longitude	Latitude	Altitude	R. humidity	Temperature
Afgoi	45.13	2.13	83.00	66.00	28.70
Afmadow	42.06	0.51	29.00	64.00	31.00
Alessandra	42.70	0.50	25.00	67.00	29.00
Alulla	50.75	11.96	6.00	72.00	29.50
Baidoa	43.66	3.13	487.00	58.00	28.20
Bardera	42.30	2.35	116.00	61.00	31.50
Belet-weyne	45.21	4.70	173.00	57.00	30.00
Berbera	45.03	10.43	89.00	77.00	25.70
Bosaso	49.18	11.28	6.00	74.00	26.20
Brava	44.03	1.10	6.00	78.00	27.00
Bulo-burti	45.56	3.25	158.00	57.00	30.60
Burao	45.56	9.51	1032.00	54.00	22.70
Bur-hakaba	44.06	2.78	194.00	51.00	29.70
Capeguardaf	51.25	11.81	244.00	79.00	24.60
Erigavo	47.36	10.61	1744.00	54.00	16.80
El-bur	46.61	4.68	175.00	57.00	29.10
Galcayo	47.43	6.85	302.00	60.00	27.50
Genale	44.75	1.83	69.00	74.00	28.10
Giumbo	42.60	-0.21	30.00	75.00	26.00
Hargeisa	44.08	9.50	1326.00	65.00	21.60

Huddur	43.90	4.16	500.00	45.00	28.70
Jonte	42.46	-0.33	8.00	75.00	28.60
Las-anod	47.36	8.46	705.00	78.00	23.00
Luuq	42.45	3.58	165.00	47.00	33.20
Mahaddeiuen	45.51	2.95	125.00	57.00	27.30
Mogadisho	45.35	2.03	9.00	78.00	28.00
Kismayo	42.43	-0.36	8.00	76.00	28.20
Obbia	48.56	5.33	10.00	75.00	27.70
Scushuban	50.23	10.3	344.00	61.00	26.70
Sheikh	45.18	9.91	1441.00	64.00	18.20
Qardo	49.08	9.50	810.00	60.00	24.70

Method

Temperature-humidity index (THI) calculations

It was done using long-term temperature and relative humidity data from THI calculation (SAWLIM). In the calculation of THI for cattle, the equation reported by the NRC (1971) was used.

$$THI = (1.8\,x\,T + 32) - [(0.55 - 0.0055\,x\,RH)x\,(1.8\,x\,T - 26)] \qquad (1)$$

In studies obtained from the literature, THI limit values for heat stress in cattle do not < stress (THI <68), mild stress (68 <THI <72), stress (72 <THI <75), severe stress (75 <THI <79), danger limit (79 < THI <84) and emergency (THI> 84). Thi equality specified by Marai et al. (2007) was used to estimate THI in sheep and goats.

$$THI = T - (0.31 - 0.0031\,x\,RH)x(T - 14.4) \qquad (2)$$

T in equations, average monthly temperature); RH (monthly relative humidity) refers to its values.

Marai et al (2007) defined THI threshold values for sheep and goats under the category THI <22.2, no heat stress, 22.2 ≤ THI <23.3 mild stress 23.3 ≤ THI <25.6 severe heat stress, THI ≥ 25.6 hazard limit category.

Interpolation Methods

The process of estimating the value of any point using sampling values taken from different regions in a field is called interpolation. In other words, intermediate values are used for calculation by taking advantage of known values in a range. Today, spatial interpolation methods express the data collected from the points known as the coordinates in CBS applications. Two different interpolations are used in the literature, which is going to stochastic and deterministic methods (Isaaks and Srivastava, 1989; ESR, 2003). Monthly spatial distribution maps were created using THI values and stochastic-deterministic methods. The interpolation methods and the best model selection are shown in Figure 2 in the flowchart.

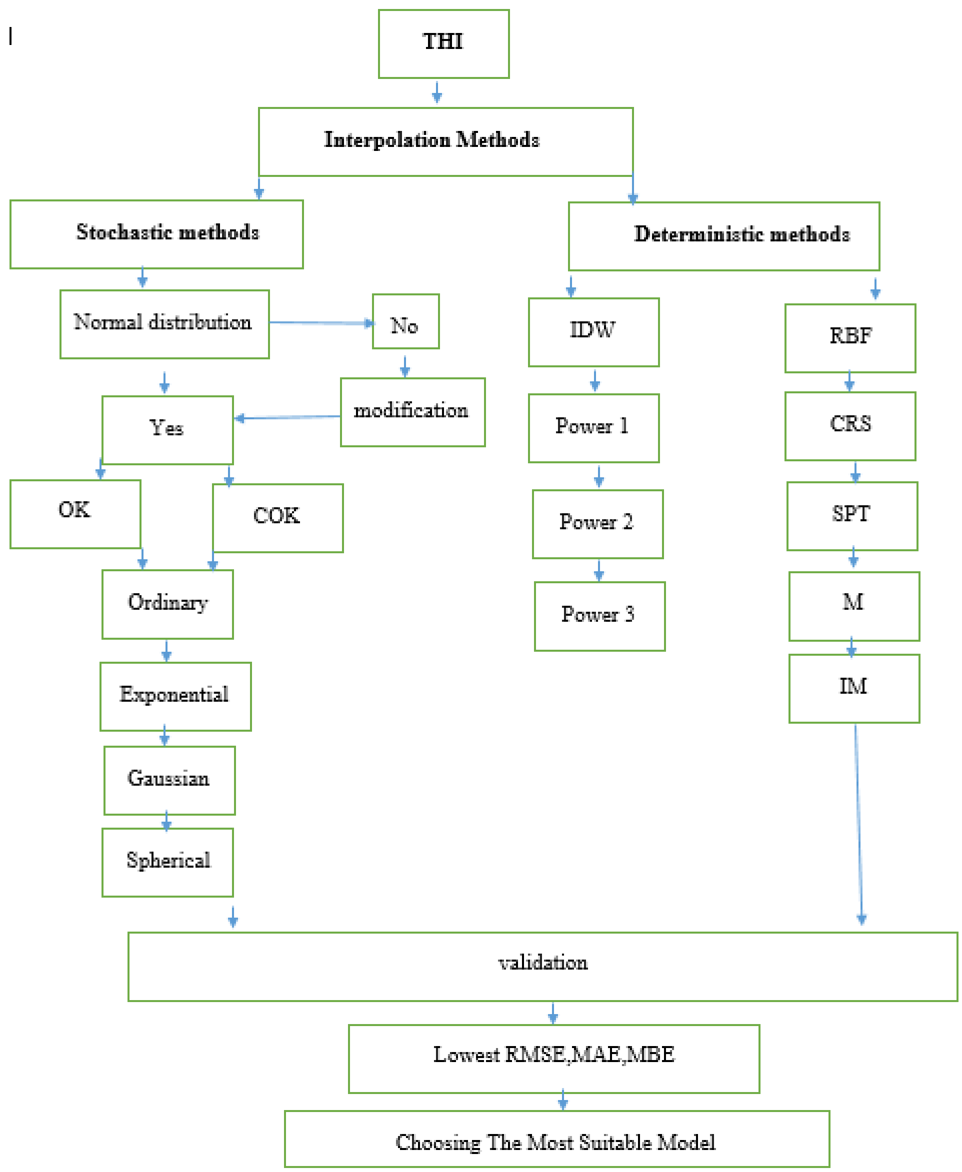

Figure 2. Different interpolation methods and best model selection flowchart to estimate THI

Stochastic methods

Stochastic methods consider both mathematical and statistical functions in a way that can reveal uncertainties and errors in the forecasting process (ESR 2003). Stochastic methods are also known as basic kriging. Kriging is an interpolation method that considers spatial changes (variograms).

Kriging methods can be classified as Ordinary kriging (OK), Block kriging (BK), Disjunctive kriging (DK), Universal kriging(UK), Indicator Kriging (IK), and Co-kriging (CoK).

In this study, OK and CoK methods were used. The OK method is a kriging method in which the variable's value at a single point is estimated when there are no trends in the data. The most used models are exponential, spherical, and Gaussian functions (Cemek et al., 2007, Zhou et al., 2012, Arslan, 2014). The COK method predicts the other for the two variables that are associated with each other.

Exponential, spherical, and Gaussian functions, sub-models of the OK method from stochastic methods, were used to create THI distribution maps of Somalia. In the CoK method, latitude is entered as a second variable next to longitude inputs (altitude, humidity, and temperature).

Deterministic methods

Deterministic methods use mathematical functions in interpolation. The most used deterministic methods are Inverse Distance Weight (IDW) and Radial Based Methods (RBF) (Dodson and Marks, 1997; Thornton et al., 1997; Kurtzman and Kadmon, 1999; Goovaerts, 2000; Liv et al., 2000; Tsansis and Gad in 2001; Anderson in 2003; Diodato and Ceccarelli in 2005; Wei et al., 2005).

The IDW method uses an unbiased weight matrix based on the distance from the unknown value to the point where the known value is. In the RBF method, the properties of the enterpoleized surfaces pass precisely through their points and have the lowest folds.

In the study, deterministic methods, completely regularized spline (CRS), spline with tension (SP), multi-quadratic (M), and Inverse Multiquadratic (IM) were used from deterministic methods and sub-models of the RBF method. The IDW method creates distribution maps according to the best model using the Power 1, 2, and 3 models.

Evaluation of models

In this study, a standard deviation of the estimated error (RMSE), mean absolute error (MAE) and average absolute error (MBE) were used in the comparison of models.

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left[THI_{m,i} - THI_{Es,i}\right]^2} \tag{3}$$

$$MBE = \frac{1}{N}\sum_{i=1}^{N}\left[THI_{mi} - THI_{Es,i}\right] \tag{4}$$

$$MAE = \frac{1}{N}\sum_{i=1}^{N}\left|THI_{mi} - THI_{Es,i}\right| \tag{5}$$

RESULTS AND DISCUSSION

Estimation and Mapping with Interpolation Methods

Within the study's scope, THI values for 31 stations were obtained. It is made to accurately estimate the THI at uncalculated points by using the THI at the calculated points. Stations in the workspace are given in Figure 3.

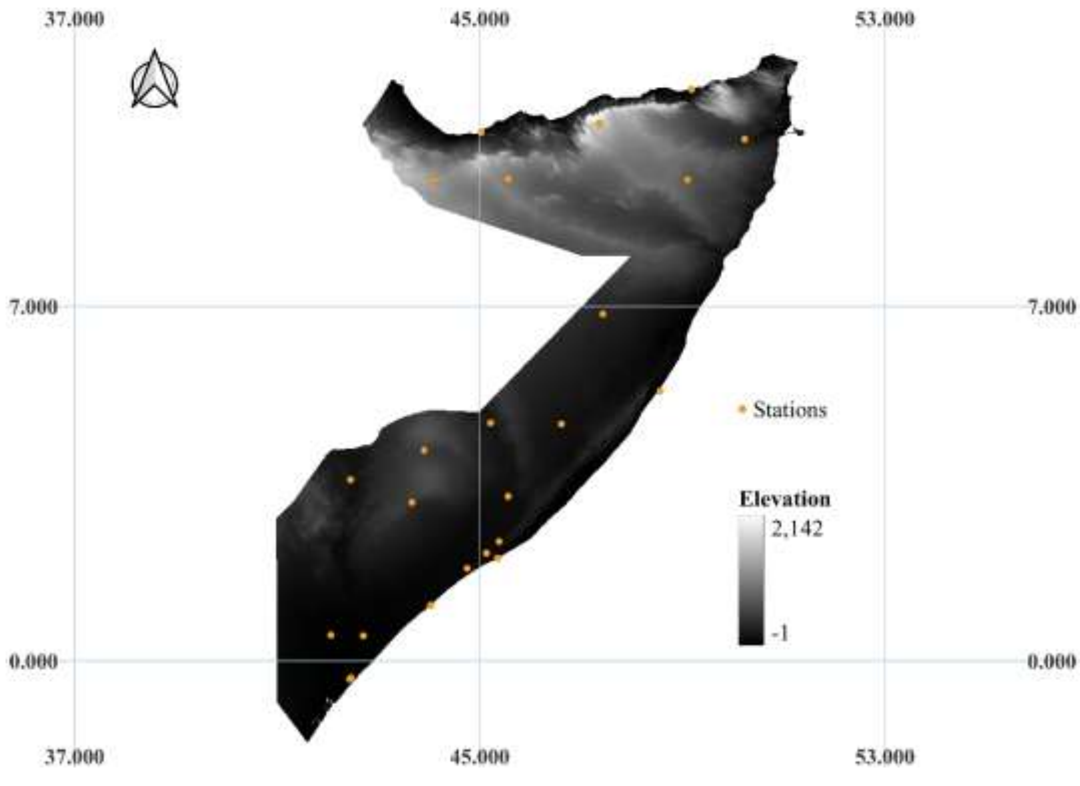

Figure 3. Station distributions of data used in the workspace

Table 4. Sheep data prediction results for the OK method

Model	Spherical			Exponential			Gaussian		
Months	MAE	MBE	RMSE	MAE	MBE	RMSE	MAE	MBE	RMSE
January	0.019	1.596	5.597	-0.012	1.680	6.344	**0.012**	**1.555**	**5.249**
Febuary	0.134	1.644	6.122	0.134	1.644	6.122	**0.123**	**1.613**	**5.948**
March	0.024	1.574	5.684	0.024	1.574	5.684	**0.007**	**1.421**	**4.603**
April	0.088	1.429	6.060	0.121	1.417	5.923	**0.083**	**1.414**	**5.888**
May	0.116	1.797	10.343	**0.163**	**1.759**	**10.007**	0.103	1.792	10.117
June	0.100	1.823	11.030	**0.141**	**1.784**	**10.788**	0.098	1.823	10.933
July	0.083	1.723	9.054	**0.117**	**1.723**	**8.755**	0.068	1.694	8.835
August	0.000	1.485	5.420	0.000	1.485	5.420	**0.000**	**1.485**	**5.420**
September	0.014	1.378	4.927	0.035	1.426	5.347	**0.003**	**1.372**	**4.728**
October	0.015	1.753	7.363	0.031	1.778	7.566	**0.075**	**1.610**	**6.281**
November	0.069	1.627	6.451	0.102	1.625	6.420	**0.075**	**1.610**	**6.281**
December	0.012	1.519	6.370	0.024	1.568	6.766	**-0.005**	**1.506**	**6.183**

Table 5. Estimate results for cattle data of the OK method

Model	Spherical			Exponential			Gaussian		
Months	MAE	MBE	RMSE	MAE	MBE	RMSE	MAE	MBE	RMSE
January	0.200	2.801	17.156	**0.251**	**2.771**	**16.881**	0.206	2.784	16.928
Febuary	0.247	2.797	16.836	0.247	2.797	16.836	**0.250**	**2.782**	**16.605**
March	0.230	2.589	14.772	0.230	2.589	14.772	**0.224**	**2.564**	**14.489**
April	0.057	2.299	15.976	0.071	2.289	16.334	**0.044**	**2.322**	**15.606**
May	0.180	2.887	28.172	**0.265**	**2.803**	**27.386**	0.169	2.872	27.758
June	0.161	2.820	27.796	**0.218**	**2.748**	**27.125**	0.164	2.821	27.563
July	0.118	2.609	21.673	**0.179**	**2.592**	**20.981**	0.091	2.543	21.094
August	0.148	2.724	21.791	0.099	2.728	21.293	**0.099**	**2.658**	**20.828**
September	0.399	3.581	25.719	0.053	2.285	13.858	**0.011**	**2.196**	**12.263**
October	0.074	2.759	17.340	0.079	2.756	17.439	**0.080**	**2.732**	**17.032**
November	0.122	2.720	17.874	0.183	2.713	17.771	**0.133**	**2.695**	**17.424**
December	0.122	2.720	17.874	0.045	2.573	19.111	**0.001**	**2.496**	**17.188**

Table 6. Estimate results of sheep and cattle data according to COK method

	Sheep			Cattle			
Months	MAE	MBE	RMSE	MAE	MBE	RMSE	Model
January	0.015	0.904	1.135	0.033	1.423	1.822	Gaussian
Febuary	0.011	0.822	1.024	0.022	1.291	1.630	Gaussian
March	0.005	0.802	1.066	0.016	1.248	1.669	Gaussian
April	0.021	0.728	0.996	0.047	1.186	1.653	Gaussian
May	0.162	0.957	1.220	0.226	1.546	2.232	Gaussian
June	0.015	1.310	1.743	0.034	1.971	2.720	Exponential
July	-0.097	1.208	1.577	-0.099	1.697	2.490	Exponential
August	-0.050	0.975	1.240	-0.073	1.513	1.946	Exponential
September	0.034	0.789	1.058	0.043	1.273	1.706	Gaussian
October	0.123	0.922	1.254	0.136	1.372	1.908	Gaussian
November	-0.036	0.714	1.025	-0.057	1.133	1.610	Gaussian
December	0.033	1.423	1.822	-0.056	1.006	1.393	Gaussian

Stochastic Methods

Both sheep and cattle were evaluated according to the OK and CoK stochastic methods. The estimate results for sheep and cattle data obtained using exponential, gaussian, and spherical variograms, sub-models of the OK method, are given in Tables 4 and 5, respectively. The Gaussian is the one that gives the most accurate result in both charts. The RMSE, MBE, and MAE values obtained for sheep and cattle from the analysis results are given in (Table 6). In the CoK method, the Gaussian model has given the most accurate results for January, February, March, April, May, September, October, November, and December, and the Exponential model for June, July, and August.

Table 7. Estimate results according to sheep data in IDW method

Model	Power 1			Power 2			Power 3		
Months	MAE	MBE	RMSE	MAE	MBE	RMSE	MAE	MBE	RMSE
January	**0.058**	**1.528**	**5.259**	0.052	1.645	6.042	0.042	1.698	6.642
Febuary	**0.060**	**1.524**	**5.213**	0.058	1.644	6.010	0.050	1.697	6.618
March	**0.086**	**1.456**	**4.779**	0.090	1.550	5.383	0.084	1.597	5.879
April	**0.091**	**1.385**	**5.546**	0.120	1.419	6.141	0.128	1.465	6.564
May	**0.072**	**1.748**	**8.922**	0.092	1.782	9.827	0.092	1.810	10.276
June	**0.047**	**1.780**	**9.881**	0.086	1.786	11.067	0.103	1.817	11.693
July	**0.041**	**1.666**	**7.788**	0.081	1.699	8.662	0.090	1.775	9.168
August	**0.039**	**1.642**	**7.184**	0.089	1.699	7.906	0.092	1.768	8.297
September	**0.077**	**1.386**	**4.639**	0.097	1.426	5.084	0.104	1.479	5.376
October	**0.054**	**1.573**	**5.606**	0.067	1.665	6.399	0.066	1.722	7.107
November	**0.049**	**1.534**	**5.462**	0.048	1.617	6.033	0.044	1.660	6.561
December	**0.071**	**1.519**	**5.840**	0.046	1.594	5.948	0.088	1.625	7.022

Table 8. Estimate results according to cattle data in IDW method

Model	Power 1			Power 2			Power 3		
Months	MAE	MBE	RMSE	MAE	MBE	RMSE	MAE	MBE	RMSE
January	**0.078**	**2.483**	**14.385**	0.037	2.695	16.451	0.027	2.765	18.055
Febuary	0.083	2.466	14.225	0.055	2.676	16.364	**0.042**	**1.698**	**6.642**
March	**0.122**	**2.321**	**12.883**	0.099	2.513	14.463	0.097	2.595	15.793
April	**0.137**	**2.295**	**15.464**	0.158	2.270	17.173	0.172	2.346	18.327
May	**0.103**	**2.796**	**24.378**	0.110	2.879	26.935	0.107	2.899	28.130
June	**0.057**	**2.721**	**24.947**	0.101	2.753	28.151	0.133	2.807	29.842
July	**0.033**	**2.475**	**18.289**	0.076	2.534	20.301	0.089	2.652	21.443
August	**0.037**	**2.530**	**17.401**	0.095	2.582	19.084	0.099	2.671	19.930
September	**0.102**	**2.224**	**11.863**	0.106	2.254	12.871	0.119	2.330	13.523
October	**0.084**	**2.556**	**15.102**	0.093	2.699	17.052	0.096	2.797	18.803
November	**0.075**	**2.515**	**15.176**	0.055	2.624	16.643	0.049	2.690	18.017
December	**0.112**	**2.509**	**16.277**	0.116	2.527	18.056	0.118	2.607	19.182

Table 9. Forecast results according to sheep data in RBF method

Model	CRS			SP			M			IM		
Months	MAE	MBE	RMSE	MAE	MBE	RMSE	MAE	MBE	RMSE	MAE	MBE	RMSE
January	-0.024	1.513	5.280	**-0.023**	**1.508**	**5.249**	-0.031	1.730	7.252	-0.020	1.553	5.417
Febuary	-0.023	1.507	5.234	**-0.022**	**1.505**	**5.201**	-0.026	1.721	7.256	-0.019	1.550	5.362
March	-0.008	1.460	4.792	**-0.007**	**1.453**	**4.777**	0.000	1.621	6.256	-0.009	1.504	5.037
April	0.010	1.383	5.530	0.011	1.387	5.484	**0.048**	**1.608**	**7.863**	**0.020**	**1.484**	**5.344**
May	0.007	1.753	8.919	0.007	1.749	8.822	**0.037**	**1.963**	**12.683**	**0.014**	**1.690**	**7.931**
June	-0.003	1.791	9.866	-0.004	1.787	9.747	**0.052**	**2.058**	**14.028**	**0.008**	**1.720**	**8.515**
July	-0.011	1.680	7.829	-0.013	1.676	7.737	**0.035**	**1.929**	**11.241**	**-0.008**	**1.610**	**6.862**
August	-0.030	1.642	7.253	-0.033	1.643	7.173	**0.009**	**1.845**	**10.281**	**-0.053**	**1.641**	**6.469**
September	0.002	1.380	4.622	**0.003**	**1.377**	**4.593**	0.033	1.496	6.052	0.021	1.383	4.568
October	-0.027	1.582	5.692	**-0.026**	**1.582**	**5.650**	0.024	1.827	8.301	-0.031	1.612	5.728
November	-0.030	1.543	5.528	**-0.028**	**1.542**	**5.513**	-0.005	1.739	7.577	-0.039	1.593	5.783
December	-0.007	1.529	5.851	-0.006	1.530	5.798	**0.019**	**1.687**	**8.267**	**0.007**	**1.542**	**5.634**

Table 10. Forecast results according to cattle data in the RBF method

Model	CRS			SP			M			IM		
Months	MAE	MBE	RMSE	MAE	MBE	RMSE	MAE	MBE	RMSE	MAE	MBE	RMSE
January	-0.028	2.508	14.517	**-0.023**	**2.499**	**14.433**	-0.053	2.867	19.960	-0.011	2.535	14.788
Febuary	-0.025	2.487	14.354	**-0.020**	**2.478**	**14.259**	-0.038	2.838	20.071	-0.006	2.535	14.583
March	0.000	2.354	13.021	**0.005**	**2.352**	**12.974**	0.003	2.690	17.301	0.004	2.409	13.538
April	0.026	2.285	15.427	0.030	2.296	15.287	**0.072**	**2.609**	**22.313**	0.066	2.471	14.702
May	0.013	2.787	24.377	0.015	2.783	24.103	**0.046**	**3.178**	**34.953**	0.039	2.714	21.499
June	-0.005	2.744	24.902	-0.004	2.739	24.585	**0.079**	**3.198**	**35.870**	0.030	2.651	21.372
July	-0.030	2.500	18.438	-0.030	2.494	18.218	**0.031**	**2.897**	**26.684**	-0.016	2.412	16.165
August	-0.054	2.525	17.608	-0.056	2.520	17.415	**-0.006**	**2.833**	**24.977**	-0.076	2.489	15.683
September	0.007	2.223	11.861	**0.010**	**2.216**	**11.795**	0.040	2.420	15.476	0.047	2.220	11.812
October	-0.036	2.580	15.361	**-0.034**	**2.579**	**15.259**	0.044	2.974	22.136	-0.042	2.631	15.491
November	-0.040	2.534	15.395	**-0.036**	**2.537**	**15.359**	-0.012	2.843	20.934	-0.054	2.613	16.053
December	0.001	2.529	16.318	0.004	2.532	16.187	**0.025**	**2.716**	**22.655**	0.050	2.579	15.854

Deterministic Methods

The results obtained for sheep and cattle using three different weight values (Power 1, 2 and 3) in the IDW interpolation method, one of the deterministic methods, are given in Tables 7 and 8, respectively. When the charts are examined, the model that works best for sheep and cattle is determined as Power 1. In the RBF method, the results obtained for sheep and cattle using four different functions (CRS, SP, M, and IM) were given in Tables 9 and 10, respectively. From the results obtained, it was determined that the IM model for both cattle and sheep made the most accurate prediction.

In their study in Turkey, Guler (2014) and Thom (1958) determined the IK method as the best method for the values obtained using the accepted formula.

Spatial distribution maps can help significantly in finding problem points in work areas. This study determined field distributions using different interpolation methods for THI, and the values at unknown points were estimated. To show the difference between interpolation methods, field distribution maps for cattle and sheep in January-August were obtained using OK, COK, IDW, and RBF models (Figures 4 and 5). As can be seen from the maps, there are clear and pronounced differences between the models.

Furthermore, the maps were examined, and it was determined that there was an increase in heat stress as we went south in January. In May, the average THI value for cattle and sheep was 77.30 and 26.20, respectively, and heat stress increased southward. Different interpolation methods were compared in the acquisition of monthly THI field distribution maps, and maps were illustrated according to the models that gave the most accurate result. Monthly THI field distribution maps for cattle are created by determining six classes (No Stress, Mild Stress, Stress, Severe Stress, Danger Limit, and Emergency) (Figures 6 and 7).

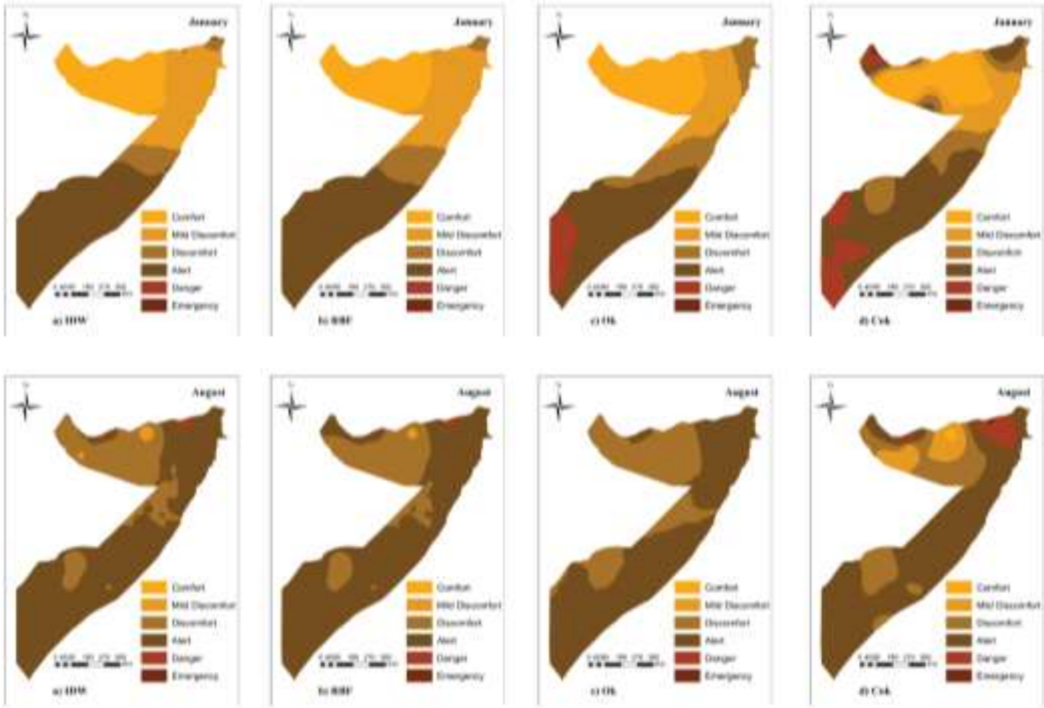

Figure 4. THI distribution maps for January and August according to different interpolation methods in cattle a)OK b) IDW C) RBF d) CoK

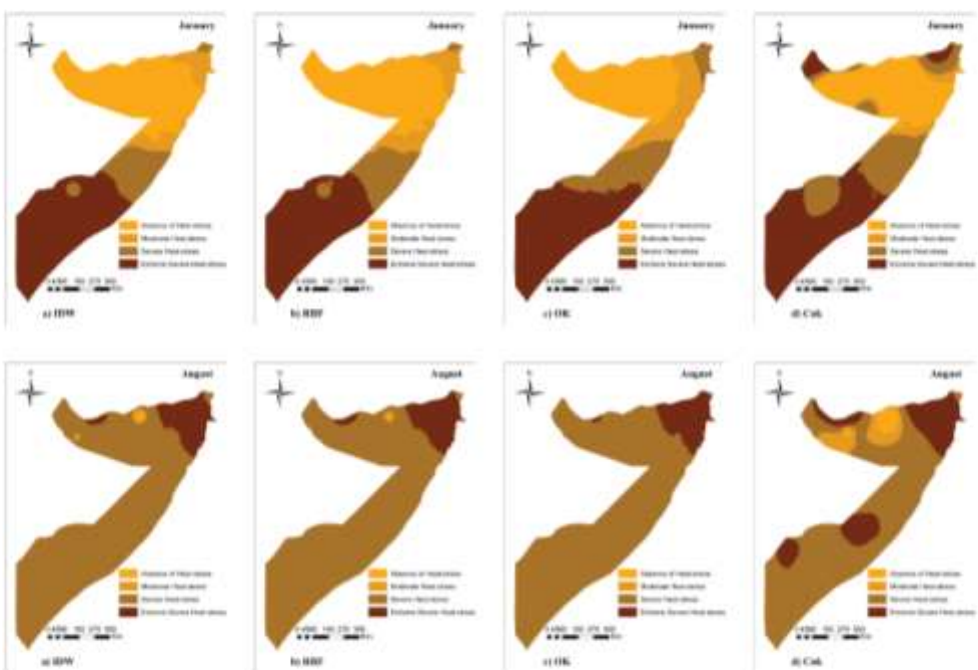

Figure 5. THI distribution maps for January and August according to different interpolation methods in Sheep a)OK b) IDW C) RBF d) CoK

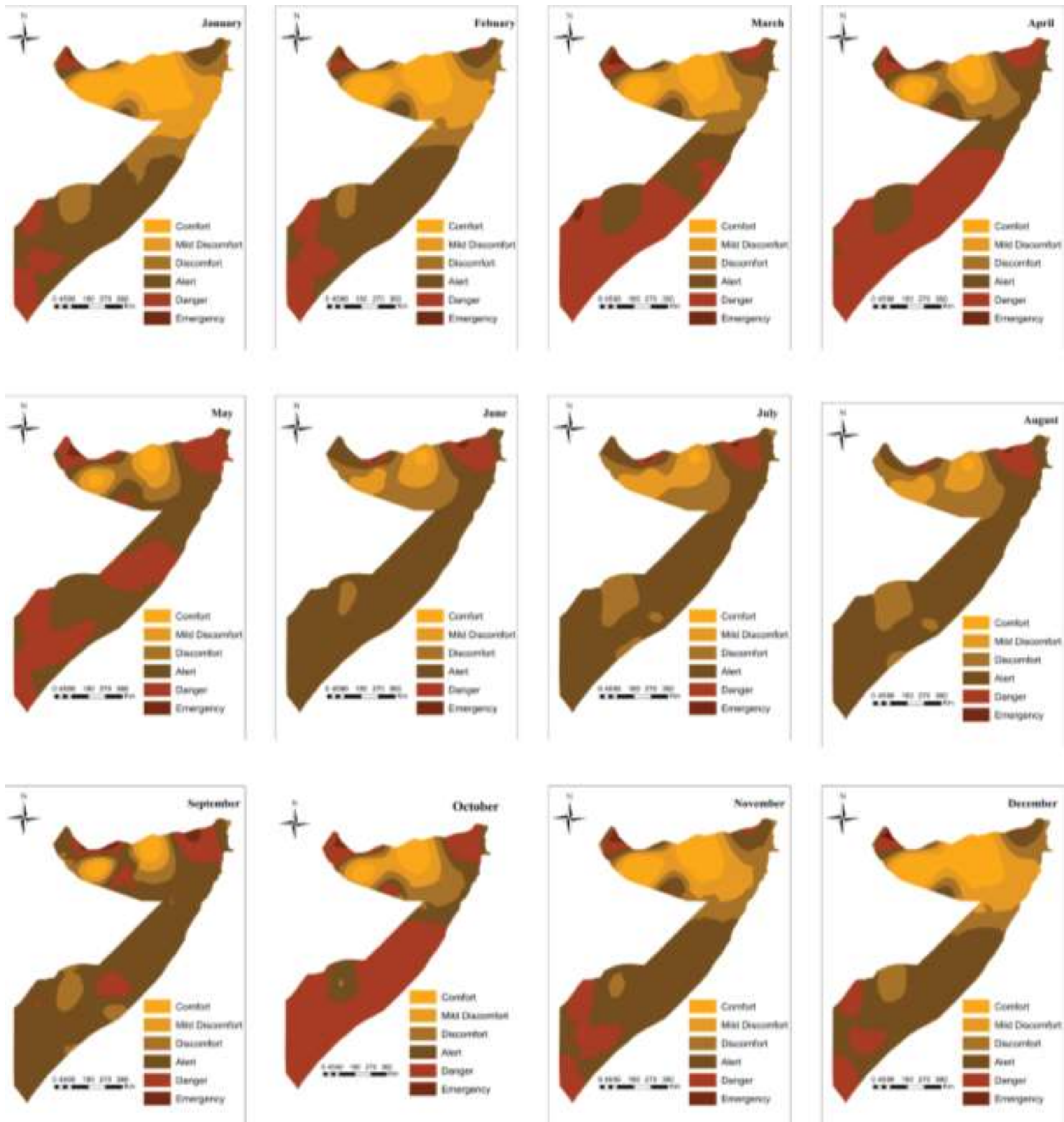

Figure 6. THI distribution maps in cattle between months by CoK method

Figure 7. THI distribution maps in Sheep between months by CoK method

Table 11. Percentage of Monthly Heat Stress for Cattle (%)

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Agu	Sep	Oct	Nov	Dec
No Stress	18.6	12.5	9.4	5.0	2.8	0.8	0.59	0.6	3.4	6.5	11.7	16.1
Mild Stress	15.0	15.8	10.4	7.3	6.0	7.9	10.15	7.8	4.0	8.3	11.8	14.1
Stress	14.6	12.5	11.3	9.7	7.3	14.8	19.75	21.8	11.0	11.2	14.4	14.1
Severe Stress	40.1	44.4	19.6	26.7	45.5	70.7	65.42	64.5	69.6	15.2	45.9	44.1
Danger Limit	11.5	15.1	41.1	49.9	38.3	5.4	4.66	4.7	10.8	58.7	14.5	11.1
Emergency	0.2	0.2	1.2	0.3	0.5	0.4	0.36	0.2	1.2	0.4	0.5	0.3

Table 12. Percentage receiving Monthly Heat Stress for Sheep (%)

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Agu	Sep	Oct	Nov	Dec
Absence of stress	29.5	22.0	15.6	9.3	5.9	3.0	3.0	2.7	5.5	10.9	18.4	24.9
Moderate stress	5.7	8.6	6.0	4.0	2.3	6.3	8.2	6.6	2.2	4.4	7.1	7.1
Severe Stres	25.2	15.8	15.5	13.5	13.1	34.2	67.4	70.0	29.6	20.6	15.2	20.8
Extreme severe	39.8	54.1	63.6	73.6	78.8	56.7	21.5	20.6	62.7	62.0	55.1	43.7

Monthly heat stress percentages for cattle and sheep are given in Tables 11 and 12, respectively. Regarding stress, severe stress, danger limit, and emergency area collection for cattle and sheep throughout the country, September has the highest percentage with 92.6%-92.3% (Table 11-12). For cattle in the no-stress class, January reached 18.6%, while the lowest was determined in July at 0.59% (Table 11). For sheep, monthly THI field distribution maps were obtained by taking into account four classes (No Stress, Mild Stress, Severe Stress, and Danger Limit) (Figures 11 and 12). In Table 12, it was determined that January was the month with the most comfort zone, with 29.5% in sheep and cattle, and August was the month with the least comfort zone, with 2.7%.

CONCLUSIONS

One of the parameters that is important for livestock activities is the heat stretch. THI, which is mostly used in determining heat stress, is an important index, and temperature, humidity, and many climate parameters (solar radiation, wind speed) are needed to make the calculations required for livestock studies. It makes it easier to measure problems encountered by easily determining these parameters. Therefore, the development of modelling studies, technological development, and the conversion of these models into the available format will allow detailed studies to be carried out. The THI calculation is influenced by many external factors (temperature, humidity, latitude, longitude, altitude). It is necessary to have a sufficient number of weather stations to receive accurate and regular data. Today, there are difficulties in obtaining these parameters, which vary by establishing weather stations. Studies in developed countries determined that climate stations, created more intensively and with parameters, are measured more precisely at more frequent intervals.

Geostatistics is studied to reveal changes in unmetered points from data at measured points. The topographical characteristics of the working area, the number of weather stations used, and the parameters discussed are evaluated depending on the factors, and the recommended methods differ. Methods that give the best results for one region can give different results for another. Climate data and THI, which show spatial distribution, should be applied in different ways depending on the region's characteristics and the structure of the existing data.

In the study, the monthly THI change field distributions were examined using geostatistics and GIS techniques in Somalia. Using geostatistic and GIS interpolation techniques to determine THI spatial distributions has produced useful results. Monthly THI was calculated for 31 stations and estimated with different interpolation methods (OK, COK, IDW, and RBF). The COK method was used to create monthly distribution maps as the most suitable method. Although IDW is simpler and more applicable among methods, it does not give as accurate results as COK.

As a result of the study, the preparation of interpolation methods and field distribution maps in a more easy way ensures widespread use. Determining temporal and spatial THI dispersion for areas with different climatic conditions worldwide, revealing animal heat stress changes, determining temperature and humidity relations, establishing livestock enterprises under the desired conditions, and playing an important role in animal production.

COK gave the most accurate results of the interpolation methods in this study. THI values exceed the threat threshold (THI 79) in March, April, May, June, July, August, and September. To prevent the adverse impacts of high temperatures and relative humidity, strategies including providing cooling fans, shading in areas with high THI values between March and September, and shifting animal feeding times to cooler hours should all be taken.

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