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Confidence limits of expected monthly rainfall for some selected stations in Peninsular Malaysia

HU HING CHONG and LIM JOO TICK

Malaysian Meteorological Service, Kuala Lumpur

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ABSTRACT. Monthly total rainfall for 15 stations in Peninsular Malaysia were analysed. The original rainfall data were normalised by Bartlett's square root transformation. Confidence limits of expected monthly rainfall were calculated from the transformed data and reconverted back to the original units. Possible applications of the confidence limits of expected monthly rainfall to agriculture are briefly discussed.

1. Introduction

Various aspects of rainfall studies in Peninsular Malaysia have been undertaken (*see* Dale 1960 and Lim 1976). Generally, it was found that there exists a seasonal variation of rainfall pattern. As stated by Manning (1960), this rainfall variability is an important factor in limiting growth and yield of rain-grown tropical crops. Such being the case, it would be extremely useful for any agricultural operation to know in advance the confidence limits of expected rainfall. It is generally agreed that 90 per cent fiducial probability of rainfall, *i.e.*, the limits within which the rainfall may be expected to lie nine years out of ten, is of practical interest to farmers. However, frequency of rainfall distribution for most stations could be shown to be highly skewed. This means that the averages and standard deviations of the rainfall data lack the necessary precision and thus could be misleading.

Several transformations can be used to normalise a set of skew data. In this paper, the logarithmic and the Bartlett's transformation were applied to the monthly rainfall data of 15 selected stations. It is found that the logarithmic transform $[y=\log(x+c)]$ is not so suitable as the Bartlett's square root transform $(y=\sqrt{x+0{\cdot}5})$, consequently, Bartlett's transformation was adopted for correcting skewness of the data.

2. Rainfall data

Fig. 1 shows the locations of the 15 selected stations in Peninsular Malaysia. Rainfall records of these stations are substantially long and range from 40 to 85 years. These records were extracted from the *Monthly Abstracts of Meteorological Observations* published by the Malaysian Meteorological Service and *Hydrological Data* published by Drainage and Irrigation Department of Malaysia.

It was found that there were some missing data in the rainfall records especially during the Second World War period (1940-1945). Hence these missing data were not considered in the analysis of the rainfall records.

3. Analysis of data and results

To test for the skewness of the rainfall data the first four moments of the frequency distribution were calculated and from which, the moment coefficient of skewness and kurtosis denoted by B_1 and B_2 respectively were computed. For perfect normal distribution, $B_1 = 0$ and $B_2 = 3$. However, small deviation from these values would not affect significantly the computations (*e.g.*, Bakthavathsalu *et al.* 1953) of confidence limits of expected rainfall.

Table 1 shows the calculated values of B_1 and B_2 of both the original frequency distribution and that of the transformed one. In general, most of the transformed data show less skewed than the original data. An example of skewness correction using Bartlett's tranformation for the frequency distribution of rainfall for Kuala Lipis is shown in Fig. 2(a) and Fig. 2(b). However, there exists a number of occasions where the

Fig. 1. Location of stations in Peninsular Malaysia

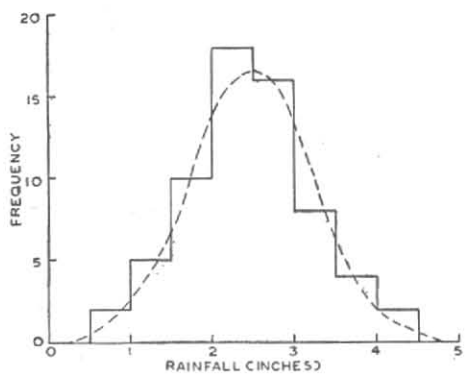

Fig. 2(a). Frequency histogram of July rainfall for Kuala Lipis, 1898-1965

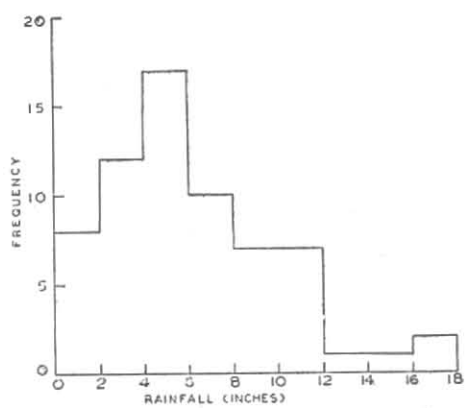

Fig. 2(b). Frequency histogram of transformed July rainfall for Kuala Lipis, 1898-1965

original data were found to be more normally distributed when compared with the transformed data. In particular several of the original monthly rainfall series of Malacca Aerodrome were found to be approximately normally distributed but, on transformation have become non-normal. In such cases, the confidence limits of expected monthly rainfall were calculated based on the original data.

The observed deviations were obtained by counting the total number of occasions of rainfall values which fall outside the confidence limits. The expected deviations are taken as $N/10$, where N is the sample size. The total observed deviations and the total expected deviations were shown in Table 2. The percentage of departures of total observed deviations from the expected deviations were computed for both the original and the transformed series. The difference gives the percentage of improvement. The results show that there are some improvement towards the theoretical expected value. Table 3 summarises the 90 per cent confidence limits of expected monthly rainfall together with the mean monthly rainfall.

Tests for normality of rainfall series using Chi-square test were performed on a number of rainfall samples (*see* Table 4). For values of B_1 and B_2 approximately equal to 0 and 3 respectively, Chi-square test indicates that the rainfall series are normally distributed at 5 per cent significant level.

On the other hand, for values of B_1 and B_2 which differ appreciably from 0 and 3, Chi-square test shows otherwise. This means that caution must be exercised when using confidence limits of expected rainfall in the case of less normally distributed series as indicated by the B_1 and B_2 values.

4. Discussion

It is known that most rainfall in Peninsular Malaysia originates from convective storms. As a result, average, whether for short intervals of time such as months and seasons or longer periods such as years are poor guides to expectation. The confidence limits with specified probability level, on the contrary, can give a fairly accurate picture of expected monthly rainfall. Maximum and minimum expected rainfall can be used by agriculturists to advantage. Depending on the type of crops, estimates can be obtained for the minimum rainfall requirement for satisfactory growth. Thus confidence limits could enable one to work out the minimum rainfall requirement for a particular crop with minimum risk.

TABLE 1

Values of coefficient of skewness

	Original data Value of		Transformed data Value of		Original data Value of		Transformed data Value of		Original data Value of		Transformed data Value of		Original data Value of		Transformed data Value of	
	B_1	B_2	B_1	B_2	B_1	B_2	B_1	B_2	B_1	B_2	B_1	B_2	B_1	B_2	B_1	B_2
	Pekan				**Alor Star**				**Kuala Kubu Baru**				**Jelebu**			
Jan	·68	3·41	·00	2·69	·53	2·75	·04	2·13	1·38	4·90	·11	2·87	·39	2·98	·00	2·61
Feb	3·52	8·22	·30	3·49	·19	1·92	·00	1·66	·04	2·40	·09	2·45	1·41	5·22	·20	3·15
Mar	·97	3·56	·08	2·38	·59	3·55	·00	2·76	1·01	4·77	·03	3·33	·94	3·59	·29	2·60
Apr	1·54	5·68	·03	4·02	·62	3·52	·01	3·21	·06	3·47	·11	3·26	·76	4·07	·02	3·40
May	·34	3·20	·00	2·76	·43	2·90	·06	2·54	·11	2·73	·02	2·71	·36	3·16	·02	2·78
Jun	·38	3·03	·00	3·03	1·40	4·84	·36	3·48	·08	2·47	·04	2·31	1·56	4·45	·43	3·15
Jul	1·37	5·29	·15	3·51	1·48	4·66	·28	3·25	·68	3·14	·09	2·61	·97	4·57	·04	3·19
Aug	·03	2·48	·13	2·89	0·29	2·53	·02	2·56	1·43	4·99	·38	3·24	2·01	7·23	·11	3·80
Sep	·50	3·42	·00	3·37	1·56	6·47	·10	4·22	·16	2·48	·01	2·33	0·28	2·89	·00	2·50
Oct	·61	4·50	·02	3·52	1·60	5·97	·37	4·25	·23	3·24	·00	2·70	·37	2·89	·05	2·34
Nov	·35	3·60	·23	5·18*	7·11	3·27	1·94	6·97	·97	3·71	·27	3·03	·32	3·35	·00	2·96
Dec	·59	2·88	·00	2·82	1·75	5·07	0·24	2·85	·44	2·90	·02	2·34	2·03	5·83	·29	3·62
	Kota Baru Aerodrome				**Kuala Lipis**				**Batu Gajah**				**Kuala Selangor**			
Jan	7·65	11·22	2·29	5·51	·88	3·66	·06	3·12	·35	2·75	·02	2·41	·03	2·77	·37	3·90*
Feb	·97	2·77	·34	2·17	1·30	4·67	·15	3·21	·01	2·23	·28	3·21	·53	2·70	·03	2·25
Mar	2·78	6·38	·51	3·03	·10	2·14	·00	1·85*	·40	3·23	·00	2·69	·43	3·00	·00	2·95
Apr	2·55	5·35	·61	3·35	·06	2·56	·06	2·60	·08	2·77	·00	2·55	·44	3·92	·14	3·66
May	·00	1·81	·71	2·10	·07	2·75	·03	2·65	1·68	6·22	·23	3·84	·38	2·92	·00	2·53
Jun	·20	2·72	·00	2·42	·72	3·59	·03	3·06	·35	3·24	·04	3·03	·80	3·83	·01	2·83
Jul	·45	2·92	·60	2·49*	·83	4·42	·00	3·01	1·89	5·32	·39	3·11	·92	4·27	·03	3·01
Aug	·25	2·90	·00	2·55	1·57	5·71	·16	3·41	·55	3·03	·08	2·38*	·19	2·70	·03	2·59
Sep	·68	3·26	·16	2·70	·17	2·94	·01	2·81	·35	3·42	·00	2·79	·13	3·18	·14	3·28*
Oct	·62	3·44	·08	2·69	·29	2·50	·03	2·25	·12	2·93	·01	2·68	·21	2·97	·12	4·04*
Nov	·11	2·66	·41	4·28*	·45	3·58	·07	3·03	·50	3·40	·07	2·74	·81	4·69	·03	4·30
Dec	·05	2·57	·42	3·46*	·90	4·92	·08	3·24	·27	3·13	·00	2·61	·03	2·76	·30	3·41*
	Kangar				**Taiping**				**Malacca Aerodrome**				**Kuala Trengganu Aerodrome**			
Jan	1·06	3·41	·24	2·23	·07	3·38	·65	5·72*	·04	1·91	·08	1·95	6·71	10·12	2·35	5·29
Feb	·85	2·80	·19	2·16	·74	3·57	·12	2·70	1·20	3·88	·08	2·58	5·03	9·18	1·19	4·22
Mar	1·58	3·90	·37	2·87	·14	2·96	·01	3·08	·19	2·97	·15	2·67*	1·64	5·04	·09	2·79
Apr	·82	4·77	·03	3·30	·14	3·38	·02	3·65	·00	3·30	·81	3·59*	4·30	8·13	·87	4·10
May	·42	3·48	·00	3·43	·59	3·85	·04	2·93	·03	2·82	1·00	3·50*	·43	3·35	·00	2·76
Jun	·04	3·08	·18	3·66*	·61	3·35	·03	2·67	·03	2·73	·55	3·34*	·20	2·75	·02	2·73
Jul	1·75	5·02	·37	3·57	·61	2·68	·11	2·21	·00	2·50	·76	3·36*	·81	3·48	·11	2·86
Aug	0·15	2·59	·00	2·38	·93	3·52	·26	2·77	·02	2·89	·79	3·97*	·40	2·90	·01	2·62
Sep	·47	3·86	·00	3·39	·02	2·22	·10	2·52	·02	2·64	1·07	3·85*	·01	2·09	·08	2·23
Oct	·23	2·25	·06	3·07	·51	4·18	·01	3·31	·01	2·78	1·16	4·00*	2·82	5·56	1·15	4·02
Nov	·04	3·04	·16	3·19*	·11	2·50	·00	2·32	·06	3·80	1·04	4·48*	·27	3·01	·00	2·53
Dec	1·19	3·63	·13	2·75	·48	3·76	·03	2·98	·20	3·92	·48	3·66	·63	3·03	·02	2·72
	Selama				**Tapah**				**Tanglin**							
Jan	·40	3·25	·00	2·70	·16	3·48	·35	5·03*	·77	3·48	·09	2·67				
Feb	2·06	5·68	·32	3·73	·54	3·86	·00	3·34	·36	2·77	·00	2·59				
Mar	·12	3·09	·05	3·20	·73	3·38	·19	2·77	·06	2·91	·04	3·00				
Apr	·95	5·72	·13	4·12	·13	2·55	·00	2·27	·20	3·41	·00	2·85				
May	·20	2·84	·00	2·63	·61	3·59	·04	3·14	·31	2·90	·01	3·16				
Jun	1·43	4·51	·44	3·10	·65	3·63	·01	2·72	·32	3·73	·02	2·87				
Jul	1·41	4·82	·06	3·20	·83	3·21	·12	2·53	·36	6·48	·00	3·69				
Aug	1·75	6·82	·16	3·85	1·29	4·25	·19	3·04	·26	2·78	·00	2·50				
Sep	·50	2·79	·07	2·38	·38	3·14	·00	2·72	2·80	9·01	·33	4·63				
Oct	·14	2·91	·00	2·75	·06	2·25	·00	2·23	0·31	3·17	·00	3·03				
Nov	1·00	3·46	·38	2·74	·22	3·02	·00	2·54	·22	2·56	·00	2·40				
Dec	1·31	4·68	·19	3·33	·37	3·72	·00	3·29	·16	2·62	·00	2·56				

*Original data show closer to normal distribution

TABLE 2

Comparison of observed deviations from expected deviations

	Observed deviations from limits		Observed deviation from limits		Observed deviation from limits		Observed deviation from limits		Observed deviation from limits	
	Original data	Transformed data	Original data	Transformed data	Original data	Transformed data	Original data	Transformed data	Original data	Transformed data
	Pekan		**Alor Star**		**Kuala Kubu Baru**		**Jelebu**		**Kota Baru Aerodrome**	
Jan	5	8	5	4	5	6	6	3	2	2
Feb	3	6	5	1	5	5	4	7	4	3
Mar	4	7	4	6	6	8	5	5	2	2
Apr	8	9	7	7	6	5	6	5	4	5
May	6	9	6	6	6	8	6	5	5	2
Jun	7	7	2	4	4	7	5	7	4	6
Jul	4	7	4	6	6	6	7	8	4	4*
Aug	9	8	6	7	4	6	3	6	2	5
Sep	6	8	4	6	7	8	6	9	3	4
Oct	7	6	4	5	6	8	5	6	3	5
Nov	5	5*	2	4	7	9	9	9	3	3*
Dec	6	6	3	5	4	8	3	6	6	6*
Total observed deviation	70	86	52	61	66	84	65	83	42	47
Expected deviation	79·2	79·2	61·2	61·2	85·2	85·2	80·4	80·4	48	48
Percentage of improvement	3·0		14·7		21·0		15·9		14·5	
	Kuala Lipis		**Batu Gajah**		**Kuala Selangor**		**Kangar**		**Taiping**	
Jan	5	7	7	10	6	6*	4	3	9	9*
Feb	4	6	8	6	7	7	7	5	5	6
Mar	2	2*	7	8	9	8	6	7	7	8
Apr	5	6	7	9	9	8	2	4	7	6
May	4	6	8	9	7	8	4	5	6	8
Jun	6	7	8	10	7	9	8	8*	4	6
Jul	4	7	6	7	6	6	4	7	6	6
Aug	3	5	6	6*	5	6	5	6	6	8
Sep	7	7	7	7	6	6*	5	6	4	9
Oct	5	7	6	9	8	8*	5	5	4	7
Nov	6	7	6	8	7	8	7	7*	6	6
Dec	2	5	6	9	6	6*	6	8	4	8
Total Observed deviation	53	72	82	98	83	86	63	71	68	87
Expected deviation	70·8	70·8	91·2	91·3	91·2	91·2	67·2	67·2	88.8	88·8
Percentage of improvement	23·4		1·6		3·3		0·6		21·4	
	Selama		**Tapah**		**Tanglin**		**Malacca Aerodrome**		**Kuala Trengganu Aerodrome**	
Jan	6	7	5	5*	7	8	3	4	3	3
Feb	5	6	6	6	9	11	4	3	3	3
Mar	7	8	6	8	7	6	2	2*	2	2
Apr	6	6	5	6	6	7	7	7*	3	5
May	4	8	10	11	8	8	6	6*	3	5
Jun	4	5	5	8	7	6	7	7*	4	6
Jul	3	7	6	10	5	9	6	6*	5	4
Aug	2	6	5	8	6	7	9	9*	4	3
Sep	5	6	7	9	5	9	6	6*	4	3
Oct	6	6	8	9	7	7	6	6*	3	3
Nov	5	6	6	6	10	7	7	7*	3	5
Dec	3	7	9	10	8	7	7	7*	5	5
Total observed deviation	59	78	78	97	83	92	70	68	42	47
Expected deviations	73·2	73·2	91·2	91·2	100·8	100·8	55·2	55·2	50·4	50·4
Percentage of improvement	12·8		8·1		8·9		3·6		9·9	

*Observed deviations obtained from original data

TABLE 3

Confidence limits for 90 per cent probability

(All units in mm)

	Mean	Confidence interval		Mean	Confidence interval		Mean	Confidence interval		Mean	Confidence interval	
		Upper	Lower		Upper	Lower		Upper	Lower		Upper	Lower
	Pekan			**Alor Star**			**Kuala Kubu Baru**			**Jelebu**		
Jan	432·3	947·2	69·1	55·1	133·6	0·0	167·1	368·3	23·6	120·6	238·0	30·2
Feb	259·6	648·7	9·7	55·9	146·0	0·0	131·6	252·2	25·9*	92·7	185·7	21·1
Mar	232·4	548·6	91·1	148·6	312·9	27·4	230·6	433·8	72·1	166·9	304·5	55·9
Apr	186·7	363·4	51·3	213·9	392·9	65·5	296·9	490·4	133·9	176·3	314·9	65·0
May	165·6	301·2	57·7	252·2	429·0	107·2	270·7	463·2	113·5	145·3	244·3*	63·0
Jun	124·2	229·1	40·9	199·6	339·3	84·6	182·6	350·2	52·8	85·9	170·7	30·2
Jul	121·9	227·1	38·3	213·9	408·1	63·2	157·2	304·0	43·7	80·3	160·3	18·5
Aug	146·5	262·4	53·3	264·4	440·1	118·9	204·2	360·1	78·5	93·2	188·5	20·3
Sep	169·0	320·3	51·3	309·3	529·5	129·8	243·8	389·6	120·9	117·6	217·9	37·8
Oct	267·2	434·5	127·3	325·3	506·2	171·4	394·2	638·1	190·5	184·1	318·5	74·4
Nov	385·3	642·4	131·8*	229·9	428·5	74·4	347·9	582·6	154·9	196·3	320·8	91·9
Dec	609·3	1283·7	122·4	105·7	251·7	5·1	232·1	458·4	60·5	198·9	396·5	49·5
	Kota Baru Aerodrome			**Malacca Aerodrome**			**Kuala Trengganu Aerodrome**			**Selama**		
Jan	213·3	604·4	0·0	91·9	223·5	2·0	232·1	633·1	0·0	221·0	448·0	51·1
Feb	82·3	205·5	0·0	86·1	215·6	0·0	118·4	310·6	0·0	225·5	443·7	59·7
Mar	103·4	276·1	0·0	146·5	299·4	0·0*	146·3	356·1	6·1	339·6	562·3	155·2
Apr	102·9	250·4	2·8	158·2	296·9	19·0*	129·8	322·8	2·3	442·7	654·3	258·8
May	126·2	261·9	24·9	162·0	300·9	23·1*	108·7	212·6	28·4	316·5	537·1	135·6
Jun	139·9	253·7	48·8	170·2	325·1	14·9*	114·0	217·9	32·5	186·9	340·3	65·0
Jul	146·3	253·7	38·6	178·8	336·3	21·1*	117·3	221·0	35·6	187·9	400·8	33·0
Aug	162·8	285·2	63·5	169·7	314·9*	24·1*	149·9	275·6	50·0	236·7	426·4	85·3
Sep	195·6	333·5	82·5	201·4	269·8	32·8*	178·8	320·5	65·3	326·4	603·4	109·2
Oct	304·8	539·7	116·3	222·2	407·2	37·3*	290·5	559·5	84·1	489·7	789·9	238·2
Nov	468·7	1143·2	154·2*	203·9	373·6	34·0*	655·6	1183·9	238·0	424·1	729·0	430·2
Dec	580·6	1065·3	95·7*	157·0	338·3	25·4	604·2	1216·9	149·1	284·5	522·4	96·8
	Tapah			**Tanglin**			**Batu Gajah**			**Kuala Selangor**		
Jan	299·4	489·4	116·6*	165·3	324·6	43·4	202·9	367·7	71·9	181·6	308·8	55·1*
Feb	245·1	432·0	94·5	160·5	321·0	38·9	165·9	306·3	54·6	120·9	267·2	15·5
Mar	346·2	573·2	158·2	231·4	363·4	119·1	231·6	418·3	83·1	133·3	273·5	28·2
Apr	402·3	624·8	212·6	268·2	426·4	134·6	270·0	417·0	144·3	166·6	339·6	37·1
May	324·8	548·6	141·0	207·5	384·0	68·6	225·0	377·1	80·0	125·5	260·1	24·6
Jun	195·3	393·7	06·2	126·5	243·3	35·6	127·5	259·8	27·7	97·3	208·0	15·2
Jul	170·9	355·1	134·3	112·8	235·7	121·1	111·0	241·5	16·0	90·9	189·1	16·8
Aug	228·3	454·1	57·9	162·3	297·1	55·1	164·0	297·7	15·5*	112·3	232·1	22·3
Sep	270·2	485·3	98·5	185·9	335·5	66·5	188·2	343·4	65·0	149·6	263·1	35·0*
Oct	418·5	686·9	195·8	286·0	479·5	126·5	292·6	485·8	132·8	228·8	385·3	70·9*
Nov	411·7	718·8	164·1	262·5	448·0	111·5	297·4	486·9	139·4	245·1	455·1	80·3
Dec	343·9	591·7	142·5	241·8	424·4	94·5	249·9	423·9	107·2	216·9	375·1	58·4*
	Kangar			**Taiping**			**Kuala Lipis**					
Jan	41·4	111·3	0·0	329·4	527·3	132·6*	225·5	431·2	66·8			
Feb	45·2	119·1	0·0	305·0	548·3	111·7	126·2	249·1	31·7			
Mar	124·2	283·7	11·9	436·3	691·9	221·0	168·1	514·1	00·0*			
Apr	178·5	319·0	65·5	497·8	744·7	284·5	210·8	374·6	79·0			
May	196·3	321·5	91·7	333·2	574·5	137·4	232·7	393·1	100·6			
Jun	170·9	268·7	72·6*	182·4	354·5	50·0	172·2	323·6	53·6			
Jul	195·3	366·5	61·5	187·4	392·9	36·6	139·7	289·8	27·9			
Aug	211·6	344·6	150·9	244·6	434·8	91·7	179·1	347·9	49·0			
Sep	277·3	454·1	130·0	307·6	556·9	110·0	215·6	366·7	91·4			
Oct	266·9	425·7	132·8	520·9	842·0	252·7	288·3	497·0	118·6			
Nov	224·8	368·3	81·0*	465·0	738·6	234·7	299·7	450·0	169·4			
Dec	87·4	205.2	4·8	372·8	610·5	175·3	269·0	461·2	112·3			

*Original data were used to calculate the confidence limits

TABLE 4

Chi-square test for normality of some selected rainfall samples

Station	Month	B_1	B_2	Chi-square test	
				Degrees of freedom	Calculated χ^2
Tanglin	Oct	·00	3·03	4	7·18*
Kuala Trengganu	Jan	2·35	5·29	7	14·70
Kuala Lipis	Jul	·00	3·01	5	1·3*
Kuala Selangor	Apr	·14	3·66	5	14·21
Pekan	Aug	·13	2·89	2	3·50*

*Indicates not significant at 5% confidence level (*i.e.*, they are normally distributed)

Examples of the use of confidence limits of expected rainfall to certain tropical crops has been reported by Manning (1960). In Peninsular Malaysia, these limits, in particular, the minimum limit, can be used for deciding the time of planting rubber or oil palm seedlings. If the minimum rainfall requirement is known, then it becomes possible to obtain a 90 per cent chance of receiving at least this amount of rainfall with a 1 : 9 risk factor. A further example of the use of the confidence limits can be seen in the case of sugarcane which generally requires a relatively long dry period prior to harvesting. Table 3 indicates that the upper limits of rainfall in Alor Star and Kangar for the months of January and February are comparatively low. This suggests that Alor Star and Kangar are ralatively dry during these two months and therefore could be suitable for sugarcane cultivation.

5. Concluding remarks

This paper clearly demonstrates that with suitable transformation, rainfall data can be adjusted to approximotely normal, enabling more meaningful calculations of means, standard deviations, upper limits and lower limits of expected monthly rainfall. With more evenly spaced stations throughout Peninsular Malaysia included in the analysis, it is possible to demarcate zones for different agricultural ventures based on these confidence limits as implied in the discussion.

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