Table 13: Best and worst values of each criterion

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
f_j^+	2.5998	3.3333	0.7142	0.7142	0.5285	0.6800	0.6000	0.6668	4.0018	2.6009
f_j^-	2.3332	2.4000	0.5074	0.5857	0.2857	0.6000	0.4000	0.6666	2.0006	2.0006

Next the value of S_i and R_i is calculated as follows:

$$s_{11} = \frac{(0.57082)\ (2.59988 - 2.33326)}{(2.59988 - 2.3332)} = 0.570692$$

$$s_{12} = \frac{(0.473438)\ (3.3333 - 3.23333)}{(3.3333 - 2.4)} = 0.050727311$$

$$s_{13} = \frac{(0.476563)\ (0.71428 - 0.692857)}{(0.71428 - 0.50743)} = 0.049356$$

$$s_{14} = \frac{(0.4625)\ (0.714286 - 0.671929)}{(0.714286 - 0.4857114)} = 0.085705$$

$$s_{15} = \frac{(0.31875)\ (0.52857 - 0.52857)}{(0.52857 - 0.285714)} = 0$$

$$s_{16} = \frac{(0.4125)\ (0.68 - 0.66)}{(0.68 - 0.6)} = 0.103125$$

$$s_{17} = \frac{(0.35625)\ (0.6 - 0.57)}{(0.6 - 0.4)} = 0.0534375$$

$$s_{18} = \frac{(0.3333)\ (0.6668 - 0.6666)}{(0.6668 - 0.6666)} = 0.3333$$

$$s_{19} = \frac{(0.562513)\ (4.0018 - 3.451471)}{(4.0018 - 2.0006)} = 0.154690$$

$$s_{110} = \frac{(0.424985)\ (2.60096 - 2.55093)}{(2.60096 - 2.0006)} = 0.035845$$

$$\begin{aligned} S_1 &= 0.570692 + 0.050723 + 0.049256 + 0.085705 + 0 + 0.103125 + 0.0534375 \\ &\quad + 0.3333 + 0.154690 + 0.035845 \\ &= 1.43677 \end{aligned}$$

$S_2 = 2.2022065$

$S_3 = 1.6095846$

$S_4 = 1.7578928$

$S_5 = 2.645818$

$R_1 = 0.570692$

$R_2 = 0.47438$

$R_3 = 0.5203116$

$R_4 = 0.3908277$

$R_5 = 0.57082$

The value of each Q_i is calculated as follows:

$$Q_1 = \frac{(0.5)\,(1.43677 - 1.43677)}{(2.645818 - 1.43677)} + \frac{(1-0.5)\,(0.570692 - 0.390827)}{(0.57082 - 0.39087)} = 0.4999$$

$Q_2 = 0.5888$

$Q_3 = 0.5237$

$Q_4 = 0.2121$

$Q_5 = 1.0000$

6.4. Experimental results and discussion

Table 14: The value of S_i and R_i

	S_i	R_i	Q_i
A_1	1.4368	0.5706	0.4999
A_2	2.2022	0.4743	0.5888
A_3	1.6095	0.5237	0.5237
A_4	1.7578	0.3908	0.2121
A_4	2.6458	0.5708	1.0000

Table 15: The ranking of the alternatives by$S$, R and Q in ascending order

	Ranking alternatives				
	1	2	3	4	5
S	A_1	A_3	A_4	A_2	A_5
R	A_4	A_2	A_3	A_1	A_5
Q	A_4	A_1	A_3	A_2	A_5

7. Same case study using traditional VIKOR method

In this section, the opinions collected from the sample respondents, whose farming experiences are mentioned in the table (1) are processed with the traditional VIKOR method. The decision makers' opinions are incorporated in the decision matrix and the aggregated decision matrix is given as follows;

Table 16: Aggregated Decision Matrix

w_j	**0.5834**	**0.4531**	**0.4609**	**0.4375**	**0.2813**	**0.4375**	**0.3438**	**0.3333**	**0.6042**	**0.3750**
A1	0.5833	0.5938	0.5938	0.5625	0.4375	0.4375	0.3438	0.3333	0.6250	0.3750
A2	0.6250	0.4375	0.4609	0.4375	0.2813	0.4375	0.3438	0.3333	0.5834	0.3750
A3	0.6944	0.4375	0.4063	0.3750	0.2917	0.4583	0.3750	0.3333	0.6667	0.3889
A4	0.5833	0.4844	0.4609	0.4375	0.2813	0.4375	0.3438	0.3333	0.5834	0.3750
A5	0.5833	0.6250	0.6250	0.6250	0.2500	0.3750	0.2500	0.3333	0.3333	0.3333

Then by applying traditional VIKOR technique, we have obtained the following results;

Table 17: The value of S_i and R_i

	S_i	R_i	Q_i
A_1	1.0131	0.3333	0.0000
A_2	2.1655	0.4531	0.6941
A_3	1.9035	0.4607	0.6052
A_4	2.2738	0.5860	1.0000
A_4	2.1877	0.5834	0.9607

Table 18: The ranking of the alternatives by S, R and Q in ascending order

	Ranking alternatives				
	1	2	3	4	5
S	A_1	A_3	A_2	A_5	A_4
R	A_1	A_2	A_3	A_5	A_4
Q	A_1	A_3	A_2	A_5	A_4

8. COMPARISON OF BOTH RESULTS DERIVED

On comparing the results obtained from newly extended VIKOR method and traditional VIKOR method, we make the following observations. The solutions obtained from the newly extended VIKOR technique shows remarkable variations in the ranking.

Table 19: Comparison of traditional and newly extended VIKOR method

	Alternative	**Rank by Traditional VIKOR Method**	**Rank by Newly Extended VIKOR Method**
$\mathbf{A_1}$	Paddy	1	2
$\mathbf{A_2}$	Sugarcane	3	4
$\mathbf{A_3}$	Urad	2	3
$\mathbf{A_4}$	Groundnut	5	1
$\mathbf{A_5}$	Tapioca	4	5

By using newly extended VIKOR technique, the sizeable change as in the table (14) represents the closeness of the group cooperation over each alternative. Whereas, the change occurred in the table (17) by using traditional VIKOR method shows an extensive variations. This actually implies the small biasness that the decision makers experience throughout the decision process. Thus the newly extended VIKOR technique avoids such considerable biasness in producing a better compromise solution.

9. CONCLUSION

The values of S_i, R_i and Q_i are calculated and the table (15) shows the best suitable solution over all such criteria. From the table (15), we conclude that the alternative Groundnut (A_4) ranks first and the alternative Paddy (A_1) ranks second and the other

alternatives Urad, Sugarcane and Tapioca rank the 3rd, 4th and 5th places respectively. The newly extended VIKOR technique shows A_4 (Groundnut) is the best compromise crop for cultivation in Villupuram district, when compared to others. Incorporating the subjective opinions into the pentagonal fuzzy numbers actually reduces the vagueness and the results obtained give a better option than the traditional VIKOR method which is shown in the table (18).

REFERENCES

[1] Devi, K., "Extension of VIKOR method in intuitionistic fuzzy environment for robot selection", Expert Systems with Applications, Elsevier Science Publishers, 38, pp. 14163-14168, 2011.

[2] Duckstein, L., and Opricovic, S., "Multiobjective Optimization in River Basin Development", Water Resources Research, 16(1), pp. 14-20, 1980.

[3] Liu, H. C., Liu, L., and Wu, J., "Material selection using an interval 2-tuple linguistic VIKOR method considering subjective and objective weights", 52, pp. 158-167, 2013.

[4] Mardani, A., Jusoh, A., and Zavadskas, E. K., "Fuzzy multiple criteria decision-making techniques and applications—Two decades review from 1994 to 2014". Expert Systems with Applications, 42, pp. 4126–4148, 2015.

[5] Mardani, A., Jusoh, A., Md Nor, K., Khalifah, Z., Zakwan, N., and Valipour, A., "Multiple criteria decision-making techniques and their applications—A review of the literature from 2000 to 2014", Economic Research Ekonomska Istrazivanja, 28, pp. 516–571, 2015.

[6] Mardani, A., Zavadskas, E. K., Govindan, K., Senin, A. A., and Jusoh, A., "VIKOR Technique: A Systemic Review of the State of the Art Literature on Methodologies and Applications", Journal on Sustainability, Molecular Diversity Preservation International and Multidisciplinary Digital Publishing Institute (MDPI), Vol. 8, No. 37, pp. 1-38, 2016.

[7] Opricovic, S., "Fuzzy VIKOR with an application to water resources planning", Expert Systems with Applications, Elsevier Science Publishers, 38, pp. 12983-12990, 2011.

[8] Pathinathan, T., and Johnson Savarimuthu, S., A Historical Overview of VIKOR Model (VIseKriterijumska Optimizacija I Kompromisno Resenje), International Journal of Multidisciplinary Research and Modern Education, Vol. 3, No. 1, pp. 1-16, (2017).

[9] Pathinathan, T., and Johnson Savarimuthu, S., Multi-Attribute Decision Making in a Dual Hesitant Fuzzy Set using TOPSIS, International Journal of Engineering Science Invention Research & Development, Vol. II, No. 1, pp. 44-54, (2015).

[10] Pathinathan, T., and Johnson Savarimuthu, S., Pentagonal Hesitant Fuzzy

Multi-Attribute Decision Making based on TOPSIS, International Journal of Technical Research, Vol. 3, No. 5, ISSN 2320-8163, pp. 250-254, (2015).

[11] Pathinathan, T., and Johnson Savarimuthu, S., Trapezoidal Hesitant Fuzzy Multi-Attribute Decision Making Based on TOPSIS, International Archive of Applied Sciences and Technology, Vol. 6, No. 3, pp. 39-49, (2015).

[12] Pathinathan, T., and Johnson Savarimuthu, S., Weight based Intuitionistic Fuzzy Set (WBIFS) and it's application to farming, International Journal of Multidisciplinary Research and Modern Education, Vol. 3, No. 1, pp. 28-39, (2017).

[13] Pathinathan, T., and Ponnivalavan, K., "Pentagonal Fuzzy Numbers", International Journal of Computing Algorithm, 3, pp. 1003-1005, 2014.

[14] Pathinathan, T., and Rajkumar., Sieving out the Poor using Fuzzy Tools, International Journal of computing Algorithm (IJCOA), Vol. 03, pp. 972-985, (2014).

[15] Pathinathan, T., Ponnivalavan, K., and Dison, E. M., "Different Types of Fuzzy Numbers and Certain Properties", Journal of Computer and Mathematical Sciences, 6(11), pp. 631-651, 2015.

[16] Raj Kumar, and Pathinathan, T., "Analysis of Poverty: Using Fuzzy Triangular Analytical Hierarchy Process", ARPN Journal of Engineering and Applied Sciences, Vol. 10, No. 12, pp. 5422-5428, (2015).

[17] Raj Kumar, and Pathinathan, T., "Sieving out the Poor using Fuzzy Decision Making Tools", Indian Journal of Science and Technology, Vol. 08, No. 22, IPL0275, (2015).

[18] Yu, P. L., "A Class of solutions for group decision problems", Management Science, Vol. 19, No. 8, 1973.

[19] Yu, P. L., "Multiple Criteria Decision Making: Concepts, Techniques and Extensions", Plenum Press, New York, U.S.A, 1985.

[20] Zadeh, L.A., Fuzzy Sets, Information and Control, Vol. 8, pp. 338-353, (1965).

[21] Zeleny, M., "Compromise Programming in Multiple Criteria Decision Making", edited by J.L.Cochrane and M. Zeleny, University of South Carolina Press, Columbia, pp. 262-301, 1973.

[22] Zeleny, M., "On the inadequacy of the regression paradigm used in the study of human judgment", Theory and Decision, D. Reidel Publishing Company, Dordrecht, Holland, 7, pp. 57-65, 1976.