is sufficient nectar and highly reduced competition among bees which often occur from overcrowding.

VI. CONCLUSION

The major interest of any beekeeper is to enhance his honey production. Avoiding overcrowding of bees in the apiary which lead to competition for nectar among bees, absconding of bees or swarming from the bee farm are essential to guide against decline in the number of colonies of the beekeeper. In this paper Crisp deterministic mixed integer honey bee productivity model was formulated in an attempt to meet the interest of the beekeepers. The mathematical model formulated was solved using Lingo 17.0 software. And the results obtained shows that optimal spatial distribution of bee will maximize the production of honey and minimize the cost of production as well as overcrowding. In other words the adoption of this model by the beekeeper will increase the production of honey and consequently its availability for human consumption.

REFERENCES

[1] A. Abdullahi, J. Isekenegbe and U. S. Mohammed, Comparative economic analysis of modern and traditional bee-keeping in Lara and Zaria Local Government Area of Kaduna State, Nigeria. International Journal of Development and Sustainability. vol 3, no 5, 2014, pp. 989-999.

[2] S. A. Ahmad, A study of search neighbourhood in the bees algorithm. Ph.D Thesis, Cardiff University.Cardiff, 2012.

[3] Ama-Ogbari, C.C.O., Apiculture as an aspect of Nigeria's economic history. Knowledge Review. vol 30, no. 1, 2014, pp. 1-9.

[4] R. Amelia, N, Anggriani, and A. K. Supriatna, Optimal control model of Verticillium lecanii Application in the Spread of Yellow Red Chili Virus, WSEAS Transactions on Mathematics, Vol.18, 2019, pp.351-358

[5] M. I. Betti, L. M. Wahl, and M. Zamir, Effects of infection on honey bee population dynamics: a model. *Journal of Public Library of Science One*, vol 9**,** no 10, 2014, pp.110–237

[6] E. Bonabeau, M. Dorigo, and G. Theraulaz, *Swarm intelligence: From natural to artificial system*. Oxford University Press. New York. 1999

[7] M. Budiharjo, P. W. Agus, and M. Abulwafa, Comparison of Weighted Sum Model and Multi Attribute Decision Making Weighted Product Methods in Selecting the Best Elementary School in Indonesia. *International Journal of Software Engineering and Its Applications*. vol 11, no 4, 2017, pp. 69-90

[8] N. O. Dike and E. Onwuka, Entrepreneur perception and growth of bee-keeping in Abia State, Nigeria. *International Journal of Physical and Human Geography,* vol 4, no. 3, 2016, pp.1-11

[9] A. M. K. Gavina, F. J. Rabajante, and R. C. Cervancia, Mathematical programming models for determining the optimal location of beehives. *Bulletin of Mathematical Biology*, vol 7, no. 6, 2014, pp .997-1016.

[10] D. Karaboga and B. A. Basturk, Powerful and efficient algorithm for numerical function optimization: Artificial Bee Colony (ABC) algorithm. *Journal of Global Optimization* vol 9, no 3, 2007, pp. 459-491

[11] D. Karaboga and B. A. Basturk, On the performance of Artificial Bee Colony(ABC) algorithm. *Applied Soft Computing*. vol. 8, no. 1, 2008, pp. 687-697.

[12] N. Khan and W. Khan, Review of past literature of honey beekeeping and its production in rural area of the world. *Food Science and Quality Management*. vol.74, 2018, pp. 18-23

[13] D. T. Pham, A. Ghanberzadeh, E. Kov, S. Otris, S. Rahim and M. Zaidi, The bees algorithm-A Novel tool complex optimization. *Intelligent Production Machines and Systems*. vol. 2, 2006, pp. 454-459

[14] N. Quijano and K. M. Passino, Honey bee social foraging algorithms for resource allocation theory and application. *American Control Conference, New York City, USA*. 2007

[15] P. E. Ramon - Joseph, C. V. Michael, and F. R. Jomar, Determining the Optimal Distribution of Bee Colony Locations to Avoid Overpopulation Using Mixed Integer Programming. *Journal of Nature Studies RM 224 (Annex),College of Science and Mathematics Building MSU- Iligan, Institute of Technology Andres Bonifacio Avenue, Tibanga,Iligan City*. 2010

[16] D. Stephens and J. A. Stevens, Simple spatially explicit ideal-free distribution: a model and an experiment, *Journal of Behavioural Ecology and Sociobiology*. vol 49**,** 2001, pp .220 - 234.

[17] E. Triantaphyllou, Multi-criteria decision making methods: a comparative study. *Springer Science and Business Media*. vol 49**,** 2013, pp **.** 5-21

[18] B.Yuce, S. M. Packianather, E. Mastrocinque, D. T. Pham, and A. Lamiase, Honey bees inspired optimization: The bees algorithm. www.mdpi.com/journal/insects/ vol 4, 2013, pp . 646-662.

8