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How Many Earths Are Needed to Support a Mole of Moles?

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Abstract
A mole is a unit for the amount of a substance so that one mole contains exactly 6.02214076×10^{23} particles, but a mole is also a furry mammal that lives underground and eats earthworms. As with all animals, they have a preferred habitat, and require sufficient space to live and grow comfortably. This paper explores how much space on the Earth is suitable for moles to inhabit and estimates how many Earths would be required to support a mole of moles.

Keywords: *Moles; Biology; Wildlife and habitat; Talpa europaea*

Introduction
A mole, previously termed a 'gram-molecule' [1] is the unit for amount of substance in the International System of Units (SI), where one mole contains exactly $6.02214076 \times 10^{23}$ specified particles of that substance [2]. This number is known as the Avogadro constant. A common definition of this is the number of atoms in 12 g of carbon-12 [3]. This paper investigates the space required to comfortably support one mole of moles, a common mammal. For this, the 'particle' is one $\text{mole}_{\text{animal}}$, therefore the calculations will be based upon $6.02214076 \times 10^{23}$ $\text{moles}_{\text{animal}}$. This is used to determine the number of Earths needed to comfortably house all the $\text{moles}_{\text{animal}}$.

Moles (animal)
As multiple species of $moles_{animal}$ exist, this paper will focus on the European mole *Talpa europaea* Linnaeus, shown in figure 1. *T. europaea* are burrowing animals that are widely distributed across Britain and continental Europe [4]. Their presence is confirmed by molehills, and they occupy a wide variety of habitats, although they are most commonly found in: lowland, grasslands, deciduous woodlands, and arable farmland [4], with their preferred habitats being mixed forests [5]. *T. europaea* avoid highly acidic soils due to the low densities of earthworms, and they also avoid waterlogged, excessively stony, and excessively sandy soils [4]. As their preferred habitat is forest, this paper will work under the assumption that moles only inhabit the forests for the purposes of calculations. Furthermore, as $\text{moles}_{\text{animal}}$ are solitary territorial mammals, with little overlap between the territories of non-breeding $\text{moles}_{\text{animal}}$ [6], it will be assumed that there is no territory overlap, and that all $\text{moles}_{\text{animal}}$ have equal territory. Data from the UK alone will be used to simplify the estimation, and this paper will assume that all the forest on the earth is inhabited by moles equally.

Figure 1 – A photograph of *Talpa europaea* showing the colouration and some of the main physiological features, like the front paws for digging, and the long snout. Photograph: [7].

Forests on Earth
The major biomes on Earth are: desert, tundra, grasslands, savannas, and forests, which correlate with the climate in each area [8]. The area of the Earth is approximately $5.1 \times 10^{14}\ m^2$ [9].

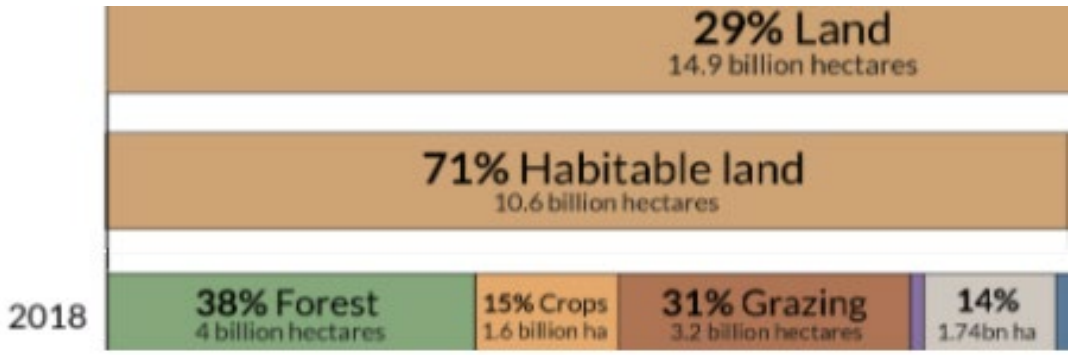

Figure 2 – A breakdown of the composition of the Earth in 2018, with the habitable land and forest figures, which are used in the calculations below. Adapted from [9].

Figure 2 shows the distribution of the area of the Earth. 29% of the Earth's area is land [9]:

$$5.1 \times 10^{14} \times 0.29 = 1.479 \times 10^{14}\ m^2 \quad (1)$$

Of this, 71% of the land is habitable, with the other 29% being comprised of barren land and glaciers [9]. The habitable land area is therefore:

$$1.479 \times 10^{14} \times 0.71 = 1.05 \times 10^{14}\ m^2 \quad (2)$$

In 2018, 38% of the habitable land was forest [9], and the area is therefore:

$$1.06 \times 10^{14} \times 0.38 = 3.99 \times 10^{13}\ m^2 \quad (3)$$

Area per mole$_{animal}$

There is estimated to be 35-40 million moles$_{animal}$ in the UK [10] and this paper will assume 40 million, as they are not an endangered species and so the population is unlikely to have decreased significantly. The area of the UK is approximately 242,495 km^2 [11], and woodland is estimated to be 13% of the total land [12]. Therefore, the total woodland and forest area in the UK is:

$$242495 \times 0.13 = 31524.35\ km^2 \quad (4)$$

To keep consistent units, this is converted to m^2:

$$31524.35 \times 10^6 = 3.15 \times 10^{10}\ m^2 \quad (5)$$

Assuming that moles$_{animal}$ inhabit all the woodland in the UK, the approximate area required per mole$_{animal}$ is:

$$\frac{(3.15 \times 10^{10})}{(4.0 \times 10^{7})} = area\ per\ mole\ (m^2) \quad (6)$$

$$788.10875\ m^2 = area\ per\ mole \quad (7)$$

Therefore, the area required for a mole of moles is:

$$788.10875 \times 6.022 \times 10^{23} = 4.75 \times 10^{26}\ m^2$$

How Many Earths?

Assuming that moles$_{animal}$ inhabit only the forest area on earth, and that the entire forest area is inhabited, then the number of earths required can be calculated using the area of the forests on Earth, calculated above, and the area that the mole of moles$_{animal}$ requires:

$$\frac{(4.75 \times 10^{26})}{(3.99 \times 10^{13})} = Earths\ required\ (8)$$

$$1.19 \times 10^{13}\ Earths\ are\ required\ (9)$$

Conclusion

From the calculations above, a thousand billion Earths would be required to provide the area of forest required to house 1 mole of moles$_{animal}$. However, this calculation is based on the assumptions that: there is one single type of moles$_{animal}$, they only inhabit forests, they inhabit all the forests in the world equally, and there is little to no overlap of their habitats. In reality, moles have more diverse habitats and so this is only an estimated value. Even with the assumptions, the number of Earths required would still likely go significantly above a billion in order to home a mole of moles$_{animal}$.

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